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Abundance, Age, Size, Sex and Coded Wire Tag Recoveries for Chinook Salmon Escapements of Kitsumkalum River, 1987-1988

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ABUNDANCE, AGE, SIZE, SEX AND CODED WIRE TAG RECOVERIES FOR CHINOOK SALMON ESCAPEMENTS OF KITSUMKALUM RIVER, 1987-1988

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TABLE OF CONTENTS

Page

LIST OF FIGURES v

LIST OF TABLES vi

LIST OF APPENDICES vii

ABSTRACT viii

RÉSUMÉ viii

INTRODUCTION 1

STUDY AREA 2

METHODS 2
- POPULATION ESTIMATION 6
  - Population Stratification 6
  - Potential Biases 6
  - Calculations 8
  - Strays 9
- TAGGING 10
- RECOVERY 11
- CODED WIRE TAGGING AND RECOVERY 13
- BIOLOGICAL SAMPLING 16
  - Scale Sampling 16
  - Calculations 17
  - Spawning Condition 17

PHYSICAL SAMPLING 17

RESULTS 18
- TAGGING 18
- RECOVERY 18
- POPULATION ESTIMATES 22
- AGE, LENGTH AND SEX COMPOSITION 24
  - Age and Length Composition 24
  - Biases in Age-Length Composition 30
- CODED WIRE TAG RECOVERY 30
  - Recoveries 30
  - Hatchery Contribution 39
- WATER LEVEL 41

TABLE OF CONTENTS (cont'd)

Page

DISCUSSION 41
POPULATION ESTIMATION 41
Escapement 41
Estimation 41
AGE, SEX AND LENGTH COMPOSITION 44

CODED WIRE TAG RECOVERIES 45

SUMMARY 47

ACKNOWLEDGEMENTS 48

REFERENCES 48

APPENDICES 50

LIST OF FIGURES

Figure Page

1 Map of the Kitsumkalum River study area. 3
2 Kitsumkalum River water level during chinook enumeration, 1987 and 1988. 42

LIST OF TABLES

Table		Page
1	Schedule of live tagging and dead recovery effort for chinook salmon, Kitsumkalum River, 1987 and 1988	4
3	Summary of rearing and release information for coded wire tagged chinook salmon recovered during escapement surveys in Kitsumkalum River in 1987 and 1988.	14
4	Summary of tagging and dead recovery of chinook salmon in the Kitsumkalum River, 1987 and 1988.	19
5	Kitsumkalum River chinook salmon tagging data and Petersen escapement estimates, 1987.	20
6	Kitsumkalum River chinook salmon tagging data and Petersen escapement estimates, 1988.	21
7	Comparison of spawning condition of female punched and unpunched chinook salmon during dead recovery on the Kitsumkalum River, 1987 and 1988.	23
8	Comparison of Petersen estimates of chinook salmon escapement totals calculated with stratified or pooled data, 1987 and 1988.	25
9	Mean length and scale condition of Kitsumkalum River chinook salmon, 1987 and 1988.	26
10	Age composition of Kitsumkalum River chinook salmon, 1987.	27
11	Age composition of Kitsumkalum River chinook salmon, 1988.	28
12	Petersen estimates of chinook salmon escapement allocated by age composition, 1987 and 1988.	29
13	Postorbital-hypural length composition of Kitsumkalum River chinook salmon at live-tagging, 1988	31
14	Sample sizes and adipose clip rates for live tagging and dead recovery samples from chinook salmon in the Kitsumkalum River, 1987.	32
15	Sample sizes and adipose clip rates for live tagging and dead recovery samples from chinook salmon in the Kitsumkalum River, 1988	33
16	Estimates of the total escapement of adipose clipped chinook salmon to the Kitsumkalum River at live tagging and at dead recovery, 1987.	34
17	Estimates of total escapement of adipose clipped chinook salmon to the Kitsumkalum River at live tagging and at dead recovery, 1988.	35
18	Weighted average estimates of total escapement of adipose clipped chinook salmon in Kitsumkalum River, 1987 and 1988.	36
19	Estimates of total escapement of chinook salmon to the Kitsumkalum River of each CWT group, 1987	37
20	Estimates of total escapement of chinook salmon to the Kitsumkalum River of each CWT group, 1988	38
21	Estimated total contribution of chinook salmon of hatchery origin to age classes represented in the 1987 and 1988 escapements in Kitsumkalum River.	40
22	Effect of removal of adipose clipped chinook salmon during live tagging on potential mark recovery in the dead pitch in the Kitsumkalum River, 1987 and 1988.	46

LIST OF APPENDICES

Appendix Page

1 Summary of live chinook salmon tagging data for the upper and lower Kitsumkalum River, 1987. 51
2 Summary of live chinook salmon tagging data for the upper and lower Kitsumkalum River, 1988. 52
3 Summary of dead pitch recovery data for chinook salmon in the upper and lower Kitsumkalum River, 1987. 53
4 Summary of dead pitch recovery data for chinook salmon in the upper and lower Kitsumkalum River, 1988. 54

ABSTRACT

Carolsfeld, J., K.K. English, P. Frank and T.M. Webb. 1990. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Kitsumkalum River, 1987 - 1988. Can. MS Rep. Fish. Aquat. Sci. 2074: viii + 54p.

The Kitsumkalum River is a major tributary of the Skeena River located near Terrace, British Columbia, and is one of the most important chinook salmon (Oncorhynchus tshawytscha) spawning streams on the northern coast. Total escapements of chinook salmon to Kitsumkalum River, escapement of coded wire tagged chinook and the contribution of hatchery production to the total escapement of chinook were estimated for 1987 and 1988. Escapements were estimated using the adjusted Petersen method, by applying tags and opercular punches to live returning adults on the spawning grounds and recovering tagged and punched carcasses following spawning. Escapement estimates were 24,508 fish in 1987 and 22,755 fish in 1988. Spawners ranged in age from 3 to 7 years old, with 6-year-old fish dominating.

Estimated hatchery contributions to adult chinook escapements in years 1987 and 1988 were 245 fish (1.03%) and 122 fish (0.54%), respectively.

Key words: Kitsumkalum, chinook, key stream, escapement, coded wire tags, age composition, hatchery, live tagging.

RÉSUMÉ

Carolsfeld, J., K.K. English, P. Frank and T.M. Webb. 1990. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Kitsumkalum River, 1987-1988. Can. MS Rep. Fish. Aquat. Sci. 2074: viii. 54 p.

La rivière Kitsumkalum est un important tributaire de la rivière Skeena, à proximité de Terrace en Colombie-Britannique. Cette rivière est l'un des principaux cours d'eau utilisés par le saumon quinnat (Oncorhynchus tshawytscha) sur la côte Ouest. L'échappée totale de saumons quinnats de la rivière Kitsumkalum, l'échappée de quinnats marqués par fils codés et l'apport de saumons d'élevage à l'échappée totale ont été estimés pour 1987 et 1988. Les échapées ont été estimées à l'aide de la méthode corrigée de Petersen: les saumons adultes revenant sur les frayères sont marqués par apposition d'étiquettes et perforation des opercules et les carcasses marquées sont récupérées après le frai. Les échappés ont été estimées à 24 508 poissons en 1987 et à 22 755 poissons en 1988. L'âge des reproducteurs variait de 3 à 7 ans, le groupe des 6 ans étant le plus important.

En 1987, l'apport total des pisicultures aux remontées de l'adult quinnat a été estimé à 245 (1.03%) et en 1988 à 122 (0.54%).

Mots clés: Kitsumkalum, quinnat, cours d'eau clé, fil codé, composition par âge, pisciculture, marquage.

INTRODUCTION

Chinook salmon (Oncorhynchus tshawytscha), the largest of the Pacific salmon, are prized by both commercial and sport fishermen. However, many chinook salmon stocks have been reduced to dangerously low levels by overfishing, so special management and enhancement actions have been undertaken in an effort to rebuild the stocks. To monitor the success of the management practices, a key streams program was initiated by the Department of Fisheries and Oceans in several important chinook salmon producing rivers throughout the province. The program began in 1984 in response to objectives set out in the Canada - U.S. Pacific Salmon Treaty. The specific objectives of the key streams program are:

1) to accurately estimate the wild escapement of salmon on key streams;

2) to estimate harvest exploitation rates and contributions to fisheries based on an analysis of coded wire tag (CWT) and adipose fin clip returns, including estimates of the total escapement of CWTs to the key stream systems; and

3) to estimate the contribution of hatchery produced fish to the total key stream escapement.

The selection of key streams was based on several criteria, including the existence of a relatively large chinook escapement, the presence of a hatchery to supply juvenile chinook for coded wire tagging, accessibility for sampling, the feasibility of capture operations, and geographical distribution to ensure that various sections of the coast are represented.

The Kitsumkalum River, a major tributary of the Skeena River and one of the most important chinook salmon spawning streams of northern British Columbia (Ginetz, 1976), was selected as a key stream. Petersen enumeration studies of the chinook escapement and enumeration of returns of coded wire tag (CWT) marked fish have been conducted since 1984 by staff at the Deep Creek Hatchery (operated by the Terrace Salmonid Enhancement Society under contract to the Department of Fisheries and Oceans (DFO)). Calculations using the spawning ground tagging information have given estimates of total escapement, while information from the coded wire tags has permitted estimates of the contribution of hatchery stocks to river escapement and has provided a basis for determining harvest exploitation rates. Initial releases of CWT fry were conducted with wild fry in 1979, and in later years with hatchery fry reared at the Kalum Pilot Hatchery at Dry Creek (MacKinlay and Fielden, 1987) and the Deep Creek Hatchery (Johnson and Longwill, 1988).

Sampling in these studies consisted of tagging live adults with external tags on or approaching the spawning grounds and recovering the tags from carcasses following spawning, in addition to enumerating fish with clipped adipose fins and CWT's. The proportion of tagged fish carcasses recovered relative to the total carcasses encountered form the basis of the Petersen estimates of escapement (Andrew and Webb, 1988). The data in past studies has been stratified by sex and geographic stream areas to avoid some of the potential biases in the escapement estimates discussed later in this report.

Andrew and Webb (1988) summarized the results of the tagging studies in this river for the years 1984-1986 and provided an analysis of the sampling procedures and calculations of the Petersen estimates. The present report summarizes the results of the studies in 1987 and 1988 and continues the discussion for optimization of the escapement estimates.

To avoid confusion in terminology of tagging and marking, the word "tagging" as used in

this report refers to the use of Ketchum Kurl-lock ear tags clipped to the operculum, "punching" refers to marking the chinook by opercular punch holes, and "marking" refers to clipping the adipose fin to indicate the presence of coded wire tags.

STUDY AREA

The Kitsumkalum River study area has been described in detail by Andrew and Webb (1988). The study area includes the mainstem river from its confluence with the Skeena River upstream to Treston Lake (Fig. 1), a distance of approximately 22 km.

The larger of two chinook runs in the river spawns principally in the study area, an earlier smaller run, not considered in this study, spawns above Kitsumkalum Lake. Chinook, pink, coho, sockeye and chum salmon all spawn in scattered locations within the study area. Of these species, pink salmon are the most abundant, followed by chinook salmon. Fisheries affecting these stocks include a sport fishery in the Kitsumkalum River and downstream commercial and Indian food fish fisheries. The principal commercial fisheries affecting chinook salmon are the seine and gillnet fisheries for pink and sockeye salmon in Statistical Area 4 (lower Skeena River).

Industrial development is present close to the confluence with the Skeena River, in association with the town of Terrace. A cedar mill operates on the east bank of the river and an abandoned mill remains on the west bank. Historically, there were log dumps and log storage in the river, but only a few log weirs now remain in side channels.

For purposes of sampling and data analysis, the study area was divided into "upper" and "lower" river portions, referring to the area upstream and downstream, respectively, of a 3 km section of canyon rapids located 10 km upstream of the Skeena River confluence (Fig. 1). This canyon is generally impassable to boat traffic, but does not constitute a barrier to salmon migration.

METHODS

Field work was conducted in the late summer and early fall as the salmon moved upstream to spawn. Actual sampling dates and effort varied in 1987 and 1988 (Table 1). Heavy rains from mid-September to the month's end in 1987 compromised the sampling goals and resulted in a low number of dead pitched salmon. In 1988, sampling was not compromised by weather, however, improvements in the local economy made it difficult to find and maintain a good crew.

Details of the methods of enumeration in this study are outlined below and summarized in Table 2.

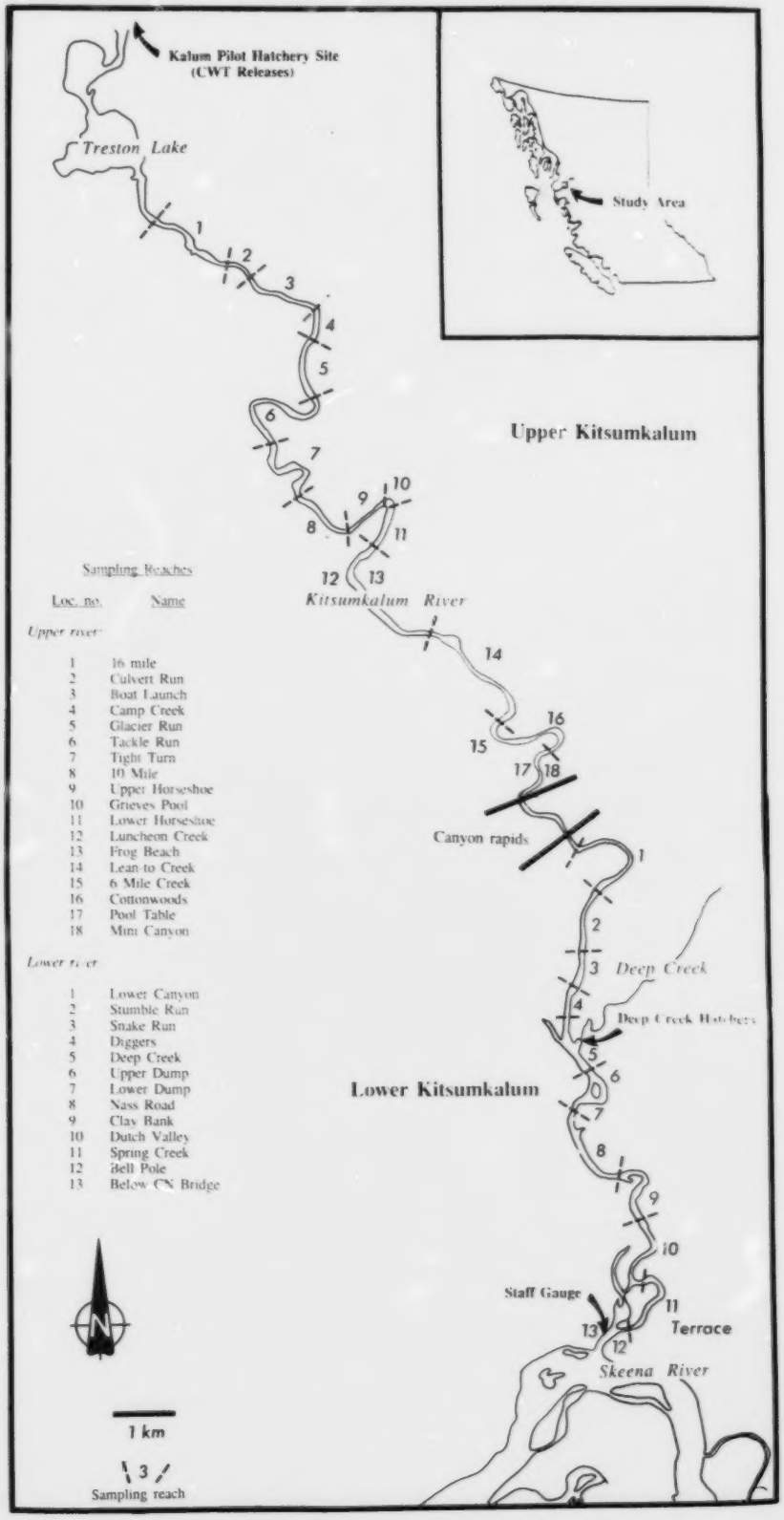


Figure 1. Map of the Kitsumkalum River study area.

Table 1. Schedule of live tagging and dead recovery effort for chinook salmon, Kitsumkalum River, 1987 and 1988.

Year	Location	Tagging period	Effort (days)	Dead recovery period	Effort (days)
1987	[a] Upper	August 21-September 8	16	August 24 - October 15	18
	[b] Lower	August 20 - September 6	13	September 8 - October 14	18
1988	Upper	August 18 - September 9	18	August 20 - October 6	25
	Lower	August 17 - September 2	13	September 12 - October 7	14

[a] Upper river is the Kitsumkalum River from Treston Lake to canyon located 10 km upstream of the Skeena/Kitsumkalum confluence (See Fig. 1).

[b] Lower river is that portion of the Kitsumkalum River downstream of the canyon to the confluence of the Skeena and the Kitsumkalum Rivers (See Fig. 1).

Table 2. Summary of methods used for chinook salmon enumeration programs on the Kitsumkalum River in 1987 and 1988.

Item	Methods
Population enumeration	• Petersen estimate, separate estimates for the sexes and upper and lower sections of the river
Tagging of fish	• Ketchum Kurl-lock ear tags clipped to operculum [a]
Secondary marking	• opercular punches [b]
Recovery of fish	• daily foot surveys, dead pitches
CWT tagging	• released 1982 to 1986 from Kalum Pilot Hatchery at Dry Creek; adipose fin clipped
CWT recovery	• collection of the heads from adipose clipped fish
Biological and Physical sampling	• ages from scales • sex ratios from population estimates based on data from separate sexes • postorbital-hypural length (mm) • success of spawning (females) • water level

[a] Manufactured by Ketchum Manufacturing Sales Ltd., 396 Berkley Ave., Ottawa, Ont., Canada K2A 2G6. The tags used (size no. 3, 1 1/8" x 1/4") are recommended for sheep and swine.

[b] A punch in the left operculum was used for fish from the upper river, and a punch in the right operculum for fish from the lower river; successive punches were applied if the fish was recaptured.

POPULATION ESTIMATION

Population Stratification

Chinook salmon were enumerated by the adjusted Petersen method (Ricker 1975, p.78) by live tagging returning adults on the spawning grounds and recovering the tags from carcasses following spawning. There are four main ways of partitioning the tagging and dead recovery data to produce an estimate of escapement (considered "stratification" in past reports, a terminology maintained in the present report):

1) sexes and upper and lower river areas pooled;

2) sexes separate with areas pooled;

3) sexes pooled with areas separate; and

4) sexes separate and areas separate.

Individual Petersen estimates may be calculated for each partition ("stratum") and then summed to obtain an estimate of the whole population. By segregating the data into separate population strata, biases caused by factors which affect the strata at different rates may be circumvented (Cousens et al., 1982). The main factors of concern for accurate estimation of escapement numbers are rates of tag application, recovery of carcasses, and tag loss. These factors may affect males, females and jacks at different rates so sexes can be subject to differential catchability for tagging and differential washout rates following spawning (affecting recovery rate).

The canyon in the Kitsumkalum River study area poses a problem for unstratified enumeration of the spawning population. If the spawners in the upper and lower rivers do not mix following tagging and form two distinct groups, then there is a potential for substantial bias if tagging or dead recovery rates and effort are not identical.

To control for potential differences in sampling and tagging rates between area and sex, the design called for Petersen estimates to be stratified by sex and area, as in the past study of Andrew and Webb (1988). The sensitivity of the population estimates to the types of stratification is examined because of concerns that stratification by area may not be valid when there is considerable mixing of fish between the two river areas, as observed in 1987 and 1988.

Potential Biases

Biases in Petersen estimates can occur when the principal assumptions of the procedure (Ricker, 1975, p.80-82) are violated. Andrew and Webb (1988) discuss the implications of violation of seven of these assumptions to the Kitsumkalum River studies, and outline appropriate tests that can be carried out to detect some of these violations. These authors' list of assumptions, based on Ricker (1975, p. 81-82) was as follows:

1) Tags are consistently applied in proportion to the available population and/or the distribution of recovery effort is proportional to the number of fish present in different river reaches and/or tagged fish become randomly mixed with untagged fish.

To obtain an accurate Petersen estimate, it is important to apply and/or recover tags in proportion to the available population. This is a fairly important problem as it affects the representativeness of sampling. However, it is not possible to test whether tagging and dead recovery were conducted on a consistent proportion of the population because there is no independent measure of the numbers of fish available for tagging and dead recovery, nor of the timing of the migration and termination of spawning, apart from the tagging and recovery data.

A related problem associated with definition of area strata is that some tagged fish stray between areas. Assuming that tagged and untagged fish stray to the same degree, this problem is circumvented to some extent by calculating correction factors to maintain the "distinctness" of the two areas. Caveats to this correction are that, as indicated above, the statistical independence of the two areas is compromised and that the corrections are inaccurate if position of the opercular punches (indicating tagging location) are not reliably recorded. A comparison of population estimates with and without stratification by area was done in this report to indicate how much this stratification may influence the accuracy of estimation.

The extent of mixing of punched and unpunched fish cannot be tested statistically with the available data, but movements of tagged fish are indicated by the location of recovery relative to the location of tagging. Tagging and recovery locations were grouped into river reaches to facilitate this comparison (see Fig. 1).

2) There is a negligible influx of spawners after the conclusion of tagging.

An influx of spawners following tagging could cause the Petersen calculations to overestimate or underestimate the true population depending on how they mix with tagged fish. It is not possible to test this assumption with the data from this study.

The loss of fish to the Skeena River during tag recovery may influence escapement estimates as well, particularly in years of high water. This can also not be tested with the present data.

3) Tagged fish suffer the same natural mortality as untagged fish.

Mortality due to tagging procedures cause Petersen calculations to overestimate the number of effective spawners. Mortality due to tagging may be indicated by reduced spawning success among tagged fish in the dead recovery. This bias is tested for in the present study by comparing the proportions of unspent tagged and untagged female fish in the dead recovery.

4) There is no tag loss.

A high incidence of tag loss will cause Petersen calculations to overestimate the true populations. To circumvent the potential bias due to primary tag loss, only opercular punch data is used for the Petersen calculations. Primary tag loss during the present study was also analysed for comparative purposes.

5) All tags are recognized and reported on recovery after the conclusion of tagging.

No re-pitches to reexamine carcasses for missed tags and secondary marks were conducted in this study, so it is not possible to evaluate tag recognition.

6) Recovery efforts are made on the same population as was tagged.

Dead recovery from a population other than the tagged population will cause Petersen calculations to overestimate the true population. Indications that tagging and recovery were conducted on different populations would be different age frequency and length frequency distributions among the samples, as well as different mean lengths. Andrew and Webb (1988) compared age and length frequencies of the tagging and recovery populations with Kolmogorov-Smirnov tests. Age data is not available for tagging populations in the present study, so only mean lengths of the two populations were compared.

7) There is adequate sampling to obtain a tag recovery rate which provides an accurate and precise population estimate.

A small number of tag recoveries in a stratum will cause Petersen estimates to have low precision. Petersen estimates are generally more reliable (precise) if a high proportion of the tagged fish are recovered in each stratum. In the absence of other sources of bias, approximately 25 to 75 recaptures will produce population estimates with 25% precision, with 95% confidence, for populations of 10^2 to 10^9 (Ricker 1975). Confidence intervals are calculated in the present study as described below, and evaluated to indicate if sampling was indeed adequate.

Calculations

The Petersen estimate for each stratum was calculated by Chapman's formula, as cited in Ricker (1975, p.78):

$$1) \quad P_{i,r} = \frac{(C_{i,r} + 1)(M_{i,r} + 1)}{(R_{i,r} + 1)}$$

where P is the population estimate, C is the total number of dead fish recovered, M is the total number of fish punched (replaced by M', which is corrected for straying, where appropriate - see below), and R is the number of dead punched fish recovered. The subscript i is the sex stratum and the subscript r is the river area stratum.

Separate estimates were made for each sex and area. A total population estimate for each year was then calculated by adding the population estimates for each stratum:

$$2) \quad P_t = \sum_{1}^{i} \sum_{1}^{r} P_{i,r}$$

The variance of each Petersen estimate of a stratum was calculated by (Ricker 1975, p. 78):

$$3)\quad S_{i,r}^2 = \frac{(P_{i,r})^2(C_{i,r} - R_{i,r})}{(C_{i,r} + 1)(R_{i,r} + 2)}$$

where S^2 is the variance of the indicated stratum and the remaining symbols are as in formula (1).

The variance for the total escapement was determined by an unweighted sum of the variances of strata as follows:

$$4)\quad S_t^2 = \sum_{1}^{i} \sum_{1}^{r} S_{i,r}^2$$

The 95% confidence intervals for each stratified population estimate were then calculated as follows:

$$5)\quad 95\%\ CL_{i,r} = P_{i,r} \pm t_{n-1}\sqrt{S_{i,r}^2}$$

and as follows for the total escapement:

$$6)\quad 95\%\ CL_t = P_t \pm t_{n-1}\sqrt{S_t^2}$$

where CL are the confidence limits, t is the tabulated t-statistic, n is the number of recoveries used for the calculation, and the remaining symbols are as in the previous equations.

Equation (3) provides an appropriate estimate of large-sample variance and has the advantage of producing symmetrical confidence intervals. Ricker (1975), however, recommends the use of confidence limits calculated from the variance of 1/P or, with small samples, calculating confidence limits by replacing the number of recoveries (R) in formula (1) with the fiducial limits taken from the Poisson distribution. Both of the latter procedures result in non-symmetrical confidence intervals. In the present study, equation (3) is used throughout for the Petersen calculations to provide continuity with the past report by Andrew and Webb (1988). Lower confidence limits are truncated to 0 if necessary.

Strays

Tagged fish moving through the canyon which divides the upper and lower sections of the river were considered to be strays from their source of tagging. Mixing (straying) of tagged fish from the upper to lower river was probably due largely to passive drift of moribund fish (Andrew and Webb, 1988). Tagged strays could be recognized by their tag numbers and the location (left or right operculum) of opercular punches if tags were lost. In 1987, opercular punch location was not as reliably recorded as in 1988. Escapement estimates in the present study were made both

with and without consideration of area stratification (upper and lower river). Only the first of these is influenced by straying of tagged fish. Comparison of these estimates in the two years gives an indication of the impact of corrections for straying, though it may also be confounded by other differential factors.

For the purpose of escapement estimates with stratification by area, the number of punched strays present in an area was calculated and used to correct the estimated total number of punched fish in each area. The total ("expanded") number of punched strays present (sexes treated separately) was extrapolated from the number of recovered strays from the dead pitch in each river area stratum (r) increased by the overall dead recovery rate calculated for each sex (i) with areas pooled:

$$7) \qquad ES_{i,r} = S_{i,r} \times \frac{M_i}{R_i}$$

where ES is the expanded number of punched strays, S is the number of punched strays recovered in the area under consideration, M is the total number of punches applied in the river, and R is the total number of punches recovered in the river.

The numbers of punched fish of each sex available for each of the upper and lower river dead recovery programs were calculated by taking the number of punched fish in each location, adding the number of punched strays that arrived from the opposite location and subtracting the number of punched strays that moved to the opposite portion of the river:

$$8) \qquad M'_{i,r} = M_{i,r} + ES_{i,r} - ES_{i,r'}$$

where M' is the number of punched fish available in area stratum r for dead recovery (upper or lower river), M is the number of punched fish released in area stratum r, and ES is the expanded number of strays in area r or in the opposite area (r'). For example, when estimating the expanded number of strays in the lower river, r represents the lower river stratum and r' represents the upper river stratum.

The Petersen estimates using data stratified by area were calculated using the corrected number of punched fish available (M') in place of the number of punches applied (M).

TAGGING

In each year there were two tagging teams of four taggers. Chinook were captured using floating gillnets (22.9 m long and 3.7 m deep). The net was allowed to drift downstream, netting fish as they congregated or moved upriver to spawn. By tending one end of the net on shore and the other in the stream from a boat, the net was kept drifting at right angles to the current before

beaching. Multifilament twine with 28 or 38 gauge filament was normally used in the nets, with a 15.2 cm stretch mesh size. When small fish began to be caught, a stretch mesh size of 23.5 cm was used with 38 gauge filament. This method allowed smaller species to escape while the chinook salmon became entangled. Gillnets were set in sections of the river where active redd building occurred until fish ripened or multiple recaptures of tagged fish began.

Captured fish were removed from the nets near the shore and species other than chinook salmon were released. Chinooks were "tailed" (tied with a braided rope with a slip knot around the caudal peduncle) to facilitate handling and prevent damage to the fish. The fish were held in shallow water in this manner with head underwater and tail exposed for from 20 seconds to 5 minutes until tagging was completed. Tailed fish remained calm and tagging mortality was low (see below).

Postorbital-hypural length (± 0.5 cm) of captured fish was measured using a fabric measuring tape. They were then visually sexed, tagged with cattle ear tags clipped to the operculum (No. 3 Kurl-lock tags manufactured by Ketchum Manufacturing Sales Ltd., Ottawa, Ontario, Canada), opercular punched, and released back to the river. Males less than 50 cm long were considered to be jacks, and enumerated as a separate category of "sex". Opercular punches consisted of a 6mm diameter hole punched in the operculum (right operculum if caught in the "upper" river and left operculum if caught in the "lower" river). These served as a secondary mark to identify those fish which had lost their tags and to indicate the river area in which the tagging had taken place. Primary tags (Kurl-lock ear tags) and opercular punches were applied to all chinook salmon that were captured, other than those that were bleeding badly or had damaged gills, which were released unmarked. Fish recaptured during tagging were marked at each successive catch site with another opercular punch.

Tagging was started in mid-August and continued until the fish were ripe, as indicated by the loss of eggs and milt during handling (early September).

RECOVERY

Two crews of workers were used for the dead recovery program. Three persons were on each crew in 1987 and four in 1988. River bars and side channels were searched regularly for carcasses. At collection sites, fish pews were used to prod the river bottom and remove fish from the turbid waters (Andrew and Webb, 1988).

Each carcass was examined for tags, opercular punches, absence of adipose fin (indicating presence of coded wire tag), sex, and spent (fully spawned) condition. Heads were removed from all fish missing the adipose fin to recover and decode coded wire nose tags. Additional data collected from the carcasses is described under biological sampling methods. Recovered carcasses were cut in two near the caudal peduncle after processing and pitched onto the river banks to eliminate them from further enumeration.

Calculations made from the dead recovery information were:

$$9)\ PR = \frac{R}{C}$$

where PR is the punch rate, an estimate of the proportion of the population marked with an opercular punch, R is the number of punched chinook recovered and C is the total number of fish recovered;

$$10)\ PRR = \frac{R}{M}$$

where PRR is punch recovery rate (the proportion of punched fish recaptured) and M is the number of tagged fish released. Similar estimates can be computed for fish tagged with Kurl-lock ear tags by using the number of tag recoveries for the values of R in the above equations.

Loss of the Kurl-lock ear tags is estimated in this report, but escapement estimates are based on the opercular punches alone, as in 1985 and 1986 (Andrew and Webb, 1988). The punches were applied to all tagged fish during the study years, so tag loss can be estimated if we assume that surveyors were able to identify all punched fish in the dead pitch sample. Kurl-lock ear tag loss was calculated by:

$$11)\ TL = 1 - \frac{R'}{R}$$

where TL is the tag loss rate, R is the total of punched fish recovered, and R' is the total fish recovered still with a tag.

The significance of primary tag loss was tested by a X^2 comparison of the total number of punched fish recovered (with or without a primary tag) and the number of fish recovered with primary tags retained (Andrew and Webb, 1988). Differences in tag loss between sexes and areas were tested with X^2 tests of fish that had lost tags (only possessed opercular punches) in these categories. Expected values of tag loss for purposes of these latter analyses were calculated from the proportion of total punched (and tagged) returns in these categories.

Mortality due to tagging was evaluated by comparing the number of spent females among the tagged and untagged fish in the dead pitch.

Lengths of fish captured during live tagging and of fish in the dead pitch in 1988 were

compared (each sex treated separately) with a Student's t-test corrected for differences in variance and sample size (Steele and Torrie, 1980) to check for differences between the tagging and recovery populations. Lengths and their residuals were assumed to be approximately normally distributed for the purposes of this test, even though a multi-modal distribution correlated with year-classes is a more accurate description. The majority of fish measured came from a single age class, so the data is likely to approach normality, and the t-test is considerably robust in the face of non-normal data. Insufficient length measurements were made in 1987 to permit this test.

CODED WIRE TAGGING AND RECOVERY

CWT's were recovered from marked hatchery fish released in 1982 to 1986. These fish represented:

1) two sets of tags used to identify fish released from the Kalum Pilot Hatchery in 1982. One group of fish came from a heated water tank and the other from an unheated environment; and

2) fish released from the Deep Creek Hatchery in 1984, 1985, and 1986.

Coded wire nose tagging (Jefferts et al., 1963) of fry and juveniles was done using methods described by Armstrong and Argue (1977) and adapted for hatchery use. Adipose fins were clipped to identify the CWT fish. Distinctive codes were used for the different groups released (Table 3). Further information on the rearing of fish released in 1982 are given by MacKinley and Fielden (1987) and for 1984, 1985 and 1986 by Johnson and Longwill (1988).

Fish were examined for presence of the adipose fin in both the tagging and dead recovery phases of the program (enumerated separately for sex and "upper " and "lower" river sections). All adipose fin clipped fish from the dead recovery program, and a portion of those caught in the tagging program, were decapitated and the heads sent to the Kitimat Hatchery for extraction of the CWT and decoding.

Estimating the total number of CWT returns from each of the brood years and for each tag code involves (Andrew and Webb, 1988):

1) determining the appropriate samples and population strata to use for estimating the overall adipose clip rate (using either the samples taken in the tagging or the dead pitch or some combination of the two based on which is the most representative sample);

2) determining the proportion of the population examined to produce the observed number of adipose clips. This is then used to calculate the total number of adipose clips estimated to be in the escapement; and

3) allocating the total number of adipose clips estimated to be in the escapement among the tag codes in proportion to those successfully decoded.

Table 3. Summary of rearing and release information for coded wire tagged chinook salmon recovered during escapement surveys in Kitsumkalum River in 1987 and 1988.[a]

Brood year	Stock[b]	Code used	Total released	Released marked (adipose clipped)	Proportion marked (%)	Release date	Release location
1981	Kitsumkalum (unheated)	O22312	30.250	23,234	76.8	May 5- 6 1982	5 km downstream of Treston Lake
	Kitsumkalum (heated)	O22313	70,400	29,459	41.8	May 5 -6 1982	5 km downstream of Treston Lake
1982	No releases	-	-	-	-	-	-
1983	Kitsumkalum	O22758	30,716	30,716	100.0	May, 1984	1.6 km upstream of of highway bridge at mouth of Kitsumkalum River
1984	Kitsumkalum	O23347	26,409	26,198	99.2	May, 1985	Kitsumkalum River at mouth of Deep Creek
1984	Kitsumkalum	O23350	26,071	25,980	99.7	May, 1985	1.6 km upstream of of highway bridge at mouth of Kitsumkalum River
1985	Kitsumkalum	O23705	42,499	42,264	99.4	May, 1986	5 km downstream of Treston Lake

[a] From Johnson and Longwill (1988)., MacKinley and Fielden (1987) and D. MacKinley, Department of Fisheries and Oceans, 555 West Hastings St., Vancouver, B.C. and G. Hazelwood, Manager, Deep Creek Hatchery, Terrace, B.C., personal communication.

[b] Except for the 1981 broodyear fish which were reared at the Kalum Pilot Hatchery all of the fish were reared at the Deep Creek Hatchery.

If the survival of unmarked hatchery fish is equal to or greater than that of marked fish, this method estimates the minimum hatchery contribution to the escapement.

Estimates of the total number of adipose clipped fish in the escapement in this study were made, both from tagging and dead recovery samples. The two estimates are equally valid if tagging and dead recovery both represent unbiased samples of the Kitsumkalum chinook salmon population. If it is assumed that this is the case (Andrew and Webb, 1988), the best estimate of total adipose clipped fish present in the river is the average of the estimates from tagging and the dead recovery weighted by sample size.

Fish were enumerated separately for males and females and river area to correspond with the stratified Petersen estimates. The dead recovery and live tagging samples were used to estimate the total number of adipose clipped fish in the escapement by:

$$11)\quad EAD_{i,r} = \frac{(OAD_{i,r})\,(P_{i,r})}{C_{i,r}}$$

where EAD is the estimated number of adipose clips, OAD is the number of adipose clips observed, C is the number of fish examined, P is the Petersen population estimate, and i and r denote sex and river area strata.

Given an estimate of the number of adipose clips escaping to the river, the escapement of each tag code can be estimated by allocation to tag codes based on their relative frequency in the sample of decoded tags:

$$12)\quad EAD_{i,r,tc} = \frac{(EAD_{i,r})(OAD_{i,r,tc})}{NDT_{i,r}}$$

where tc denotes tag code, NDT is the number of decoded tags and other symbols are as in equation (11).

As noted earlier, Ricker (1975) suggests confidence limits for Petersen estimates with small sample sizes can be calculated by considering the number of recaptures (R) a Poisson variable and carrying out calculations (formula 1) with the tabulated upper and lower confidence limits of this variable. Approximate 95% confidence limits of the adipose clipped chinook escapements were calculated in an analogous manner by considering the observed number of fin clips the Poisson variable and carrying out the calculations for upper and lower confidence limits. This was done only for the individual strata.

Adipose clipped fish that were examined but were missing a CWT were not included in the

total used to establish the relative frequencies of tag codes. However, since these fish are still represented in the total escapement of adipose clipped fish, this approach serves to distribute them proportionately over the identified tag codes. This may result in an overestimation if the fins are lost due to other reasons than CWT tagging. In the previous study (Andrew and Webb, 1988), decomposition of adipose fins was not found to be a likely reason for the presence of adipose clipped fish without CWT's.

The proportion of the population sampled during the dead pitch is estimated by the ratio of the number of dead fish recovered to the total escapement indicated by the Petersen estimates. These Petersen estimates include a correction for mixing between river areas after tagging, so the size of the fish population sampled during tagging requires recalculation. This population can be estimated by:

$$13) \quad P'_{i,r} = P_{i,r} + \frac{ES_{i,r}}{PR_{i,r}} - \frac{ES_{i,r'}}{PR_{i,r'}}$$

where P' is an estimate of the number of fish in area stratum r at the time of tagging, P is the Petersen estimate of the population at the time of dead recovery, ES is the expanded numbers of strays present in stratum r or the opposite stratum (r') and PR is the punch rate for the river area stratum.

It is not clear which punch rates (i.e. sexes pooled, areas pooled, individual upper or lower areas) are the most appropriate for estimating the population size sampled during live tagging. There is no data to indicate if factors at time of tagging or time of recovery are most influential in the recovery of stray fish, or whether these factors differ amongst sexes and areas with respect to strays. In the past report (Andrew and Webb, 1988), punch rates with sexes and areas pooled were used, while in this report distinct punch rates for sex and area are used. The punch rates are quite variable between the various groups, and can thus influence the estimated population size at tagging in the two areas considerably. The estimate of escapement of adipose fin clipped fish from live tagging data in each area is thus also considerably influenced.

Due to different ages at maturity of males and females, it is important that allocation of adipose clipped fish to tag codes is done separately for the two sexes whenever possible. The recovery of jacks has been excluded from this analysis because of small sample sizes.

BIOLOGICAL SAMPLING

Scale Sampling:

Scales for ageing purposes were randomly collected from fish over the course of the dead pitch. Preparation and reading of scales was carried out by the fish ageing laboratory of the Department of Fisheries and Oceans in Vancouver. Only non-regenerated scales and scales with a portion of the previous annulus present were considered readable. Scales were classified as unreadable if they had regenerated centres, the scale was resorbed, or the scales were mounted too

wet or upside down making it impossible to count annuli. Ages were recorded for fish that had at least 2 scales that could be read for both marine and freshwater ages. In this report, the first numeral of the age recorded indicates the year of total life and the decimal point numeral indicates the year of life in which the fish migrated to the ocean. For example a fish aged 5.2 is a 5-year-old that entered the ocean in its second year of life. This ageing system follows that described by Gilbert and Rich (1927).

The age and length analysis of the available samples is valid only if the sampling of scales from tagging and dead pitch is random and there is no bias in the readability of the scales with age. Ages of older, and hence larger, fish are usually more difficult to determine than those of younger individuals because scales tend to resorb and regenerate with age. To test for this bias, mean lengths of fish that were successfully aged were compared with those that were not, using a Student's t-test. The tests were performed for each year and for males and females separately. Appropriate corrections for unequal variances and sample sizes were made (Steele and Torrie, 1980) and an approximately normal distribution of the residuals of length data was assumed.

Calculations

The population in each age class was determined by allocating portions of the Petersen estimate to age classes according to the age composition determined from scale samples that were collected during the dead pitch.

The sex ratio in each year was determined from Petersen estimates of totals for each sex with the areas pooled. This method provides a valid sex ratio assuming that tag loss and tag recognition were not seriously biased by sex. In the past years (Andrew and Webb, 1988), there was differential tag loss for males and females, which would introduce bias into the calculations. This bias was minimized in the present study by using only opercular punch counts (apparently not effected by sex) for enumeration data, as was done for the latter years of the earlier study.

Spawning Condition

Spawning condition of recovered female carcasses was recorded as spent, partially spent, or unspent. Condition was recorded as spent if the gonads were completely empty of eggs, partially spent if some eggs remained, and unspent if the gonads were intact and all eggs appeared to be retained.

PHYSICAL SAMPLING

Water levels were monitored using a staff gauge which was mounted on the highway bridge crossing at the mouth of the Kitsumkalum River (Fig. 1).

RESULTS

TAGGING

Tagging was conducted in 14 reaches of the river in 1987 and 17 in 1988. A total of 858 tags were applied to upper river fish and 804 to lower river fish in 1987. In 1988, 785 and 894 tags were applied in the two areas respectively (Table 4 and Appendix 1 and 2). Efforts were made to tag equal numbers of fish in the two areas, which resulted in a greater tagging effort in the upper section of the river in 1988 (18 days tagging vs 13 in the lower river, see Table 1 and Appendix 2). More males were captured in the tagging program than females in both years and in both the upper and lower river (Table 4). Very few jacks were tagged in either year (75 in 1987 and 21 in 1988).

RECOVERY

Recovery of carcasses was conducted in over 27 locations in 1987 and 1988 (Fig. 1). In terms of numbers of sampling days, dead recovery effort was equal in the upper and lower river in 1987 (18 days) (Table 1 and Appendix 3). In 1988, however, 25 days of recovery effort were spent in the upper river and 14 days in the lower river (Table 1 and Appendix 4). The punch rate (proportion of the total carcasses recovered bearing opercular punches) was 7% in 1987 and 6.5% in 1988 (Table 4), which was lower than in both 1985 and 1986, but higher than 1984 (Andrew and Webb, 1988). More females than males were recovered in 1987 and 1988, even though more males were tagged in both years. Fewer jacks were recovered than either males or females (Tables 5 and 6).

Tag recovery rates (Kurl-lock ear tags) varied only slightly in the two areas in 1987, and were comparable to upper river recoveries in 1988. The lower river recovery rate in 1988, however, was considerably higher. Overall tag loss was 23.1% in 1987, compared to only 5.4% in 1988 (see Table 4). Punch recovery rates were higher in the lower river in both years, as was observed for the primary tags in 1988. Tag loss thus probably masked this trend in recovery rates of primary tags in 1987.

Tag loss rates of the Ketchum Kurl-lock ear tags (Table 4) in 1987 and 1988 (23.1% and 5.44%, respectively) were generally lower than the loss of spaghetti tags used in earlier years (29.8% and 45.7% in 1985 and 1986, respectively) (Andrew and Webb, 1988). Tag loss was nevertheless still significant over the two years (H^o: punched recovery = tag recovery (whole river); $X^2 = 7.56$, df = 1, $P < 0.01$). The difference in total tag loss between 1987 and 1988 (sexes and areas combined) was highly significant (H^o: number of tags lost (fish recovered with punch only) in the whole river are equivalent (weighted by the number of fish punched) in each year; $X^2 = 20$, df = 1, $P < 0.001$). Differences in tag loss between males and females (areas combined) was not significant in either year (H^o: number of tags lost (fish recovered with punch only) in the whole river are equivalent (weighted by the number of fish punched) for males and females; $X^2 = 0.93$ and 0.85 in 1987 and 1988 respectively, df = 1, $0.3 < P < 0.5$ for both years). Differences in tag loss between areas (sexes combined), though apparently greater in the lower

Table 4. Summary of live tagging and dead recovery of chinook salmon in Kitsumkalum River, 1987 and 1988.

Item	1987			1988		
	Upper river	Lower river	Total	Upper river	Lower river	Total
A. Tagging programs [b]						
Males tagged and punched	517	441	958	448	487	935
Females tagged and punched	305	324	629	331	392	723
Jacks tagged and punched	36	39	75	6	15	21
Total tagged and punched (= A)	**858**	**804**	**1,662**	**785**	**894**	**1,679**
B. Dead recovery programs [c]						
Males recovered	213	539	752	214	747	961
Females recovered	306	760	1,066	378	1,724	2,102
Jacks recovered	12	14	26	7	13	20
Total recovered (= B)	**531**	**1,313**	**1,844**	**609** [a]	**2,484**	**3,093**
Punch only males	6	11	17	1	5	6
Punch only females	1	11	12	1	4	5
Punch only jacks	0	1	1	0	0	0
Total punch only fish (= C)	**7**	**23**	**30**	**2**	**9**	**11**
Tagged males	26	21	47	26	50	76
Tagged females	14	39	53	26	88	114
Tagged jacks	0	0	0	0	1	1
Total tagged fish (= D)	**40**	**60**	**100**	**52**	**139**	**191**
Tag and punched males	32	32	64	27	55	82
Tag and punched females	15	50	65	27	92	119
Tag and punched jacks	0	1	1	0	1	1
Total tag and punched fish (= E = C+ D)	**47**	**83**	**130**	**54**	**148**	**202**
C. Tagging related rates (%)						
Tag rate (= D / B)	7.53	4.57	5.42	8.54	5.60	6.18
Punch rate (= E/B)	8.85	6.32	7.05	8.87	5.96	6.53
Tag recovery rate (= D/A)	4.66	7.46	6.02	6.62	15.55	11.38
Tag and punch recovery rate (= E/A)	5.48	10.32	7.82	6.88	16.55	12.03
Tag loss rate (= C/E)	14.89	27.71	23.08	3.70	6.08	5.45
Male tag loss rate	18.75	34.38	26.56	3.70	9.09	7.32
Female tag loss rate	6.67	22.00	18.46	3.70	4.35	4.20

[a] Total includes 10 fish too decomposed to sex
[b] See Appendix 1 and 2 for raw daily data for 1987 and 1988, respectively
[c] See Appendix 4 and 5 for raw daily data for 1987 and 1988, respectively

Table 5. Kitsumkalum River chinook salmon tagging data and Petersen escapement estimates, 1987 (See text for methods of calculation)

Location	Item	Male	Female	Jack	Total
Upper river	Tagged fish[a]	517	305	36	858
	Dead recovery[b]	213	306	12	531
	Tag recoveries	26	14	0	40
	Tagged strays from lower river	0	1	0	1
	Punched recoveries	32	15	0	47
	Punched strays from lower river	0	1	0	1
	Expanded estimate of strays in upper river	0	10	0	10
	Punched available for Petersen estimate	248	247	36	531
	Petersen estimate	1,612	4,757	481	6,850
	% of total	24	69	7	100
Lower river	Tagged fish[a]	441	324	39	804
	Dead recovery[b]	539	760	14	1,313
	Tag recoveries	21	39	0	60
	Tagged strays from upper river	10	4	0	14
	Punched recoveries	32	50	1	83
	Punched strays from upper river	18	7	0	25
	Expanded estimate of strays in lower river	269	68	0	337
	Punched available for Petersen estimate	710	382	39	1,131
	Petersen estimate	11,642	5,716	300	17,658
	% of total	66	32	2	100
Whole River	Petersen estimate, areas and sex stratified	13,254	10,473	781	24,508
	Lower 95% confidence limit	9,429	7,808	67	19,792
	Upper 95% confidence limit	17,078	13,138	1,495	29,223
	As (+/-) % of Petersen estimate	28.86	25.44	91.42	19.24
	Petersen estimate, areas pooled	11,110	10,185	1,026	22,321
	Lower 95% confidence limit	8,548	7,823	0	18,661
	Upper 95% confidence limit	13,672	12,547	2,143	25,980
	As (+/-) % of Petersen estimate	23.06	23.19	100.00	16.40

[a] See Appendix 1 and Table 4
[b] See Appendix 3 and Table 4

Table 6. Kitsumkalum River chinook salmon tagging data and Petersen escapement estimates, 1988. (See text for methods of calculation)

Location	Item	Male	Female	Jack	Total
Upper river	Tagged fish[a]	448	331	6	785
	Dead recovery (fish examined)[b]	214	378	7	599
	Tag recoveries	26	26	0	52
	Tagged strays from lower river	2	1	0	3
	Punched recoveries	27	27	0	54
	Punched strays from lower river	2	1	0	3
	Expanded estimate of strays in lower river	23	6	0	29
	Punched available for Petersen estimate	311	319	6	636
	Petersen estimate	2,397	4,329	56	6,782
	% of total	35	64	1	100
Lower river	Tagged fish[a]	487	392	15	894
	Dead recovery (fish examined)[b]	747	1,724	13	2,484
	Tag recoveries	50	88	1	139
	Tagged strays from upper river	12	3	0	15
	Punched recoveries	55	92	1	148
	Punched strays from upper river	14	3	0	17
	Expanded estimate of strays in lower river	160	18	0	178
	Punched available for Petersen estimate	624	404	15	1,043
	Petersen estimate	8,346	7,515	112	15,973
	% of total	52	47	1	100
Whole River	Petersen estimate, areas stratified	10,743	11,844	168	22,755
	Lower 95% confidence limit	8,506	9,727	30	19,672
	Upper 95% confidence limit	12,980	13,962	306	25,839
	As (+/-) % of Petersen estimate	20.82	17.88	82.13	13.55
	Petersen estimate, areas pooled	10,849	12,688	231	23,768
	Lower 95% confidence limit	8,631	10,493	0	20,637
	Upper 95% confidence limit	13,066	14,883	480	26,898
	As (+/-) % of Petersen estimate	20.44	17.30	100.00	13.17

[a] See Appendix 2 and Table 4
[b] See Appendix 4 and Table 4

river, was not significant in 1987 ($X^2 = 2.13$, df = 1, $0.05 < P < 0.1$) or 1988 ($X^2 = 0.41$, df = 1, $0.3 < P < 0.5$) (H^o both years: number of tags lost (fish recovered with punch only) of males and females combined are equivalent (weighted by the number of fish punched) in upper and lower river areas).

Strays from the upper river to the lower river contributed considerably to the number of fish in the lower river in both years, but the inverse was not true. Only one stray from the lower river to the upper river was found in 1987 and three in 1988 (Tables 5 and 6), while 25 strays were found in the lower river in 1987 (Table 5) and 17 in 1988 (Table 6). The strays contributed considerably to the estimates of punched fish available for Petersen estimates in the lower river in both years (30% and 17% in 1987 and 1988 respectively). 72% of the strays in the lower river were males in 1987 and 82% were males in 1988. This was a significantly higher proportion than could be expected from an equal straying behaviour of males and females in 1988 ($X^2 = 7.12$, df = 1, $0.001 < P < 0.01$) and 1987 ($X^2 = 4.84$, df = 1, $0.02 < P < 0.05$).

Female chinook salmon captured in the gillnets, tagged and subsequently recovered in the dead pitch had a high rate of spawning success (Table 7). Out of a total of 65 recovered punched carcasses examined in 1987, 62 were fully spent, while of a total of 1001 carcasses of unpunched females that were examined, 980 were fully spent. This spawning success was not significantly different between punched and unpunched females ($X^2 = 0.04$, df = 1, $P > 0.05$). In 1988, 119 punched and 1958 unpunched female carcasses were examined. Of these, 118 and 1944, respectively, were fully spent. Again, no significant difference in spawning success was detected ($X^2 = 0.00017$, df = 1, $P > 0.05$).

There was no significant difference in mean lengths of females and jacks from the tagging and carcass recovery samples in 1988 ($t = 0.42$, 3352 df in 1987, $t = 1.44$, 64 df in 1988, $P > 0.05$ both years), but a difference in the size of males was detected ($Z = 4.05$, $P < 0.05$). Males of the dead recovery were larger on the average than during tagging. No data from 1987 was available for this analysis.

POPULATION ESTIMATES

The total escapement estimates for the Kitsumkalum chinook run studied in 1987 and 1988 were 24,508 ± 4716 and 22,755 ± 3083, respectively, when stratification by both river area and sex is used. With data stratified by sex only these figures are 22,321 ± 3660 and 23,768 ± 3131 respectively (totals ± 95% CI; Tables 5 and 6, respectively). Overlapping confidence intervals indicate that the estimates with and without stratification are not different (see below). Using stratification by area and sex, 6,850 ± 2,347 escaped to the upper river and 17,658 ± 4090 to the lower river in 1987. In 1988, these figures were 6,782 ± 1,688 and 15,973 ± 2,505 respectively (Tables 5 and 6).

In 1987 the escapement of males, females and jacks in the upper river was 1612 ± 498, 4,757 ± 2,202, and 481 ± 640 fish, respectively (Table 5). For the lower river these numbers were 11,642 ± 3,792, 5,716 ± 1,501, and 300 ± 316, respectively. In 1988 (Table 6), the escapement of males, females and jacks in the upper river was 2,397 ± 814, 4,329 ± 1516, and 56 ± 73 fish, respectively and 8,346 ± 2084, 7,515 ± 1478 and 112 ± 117 in the lower river.

Table 7. Comparison of spawning condition of punched and unpunched female chinook salmon during dead recovery on the Kitsumkalum River, 1987 and 1988

Year	Item	Total examined	Number fully spent	Proportion fully spent
1987:				
	Punched females	65	62	0.954
	Unpunched females	1001	980	0.979
1988:				
	Punched females	119	118	0.992
	Unpunched females	1958	1944	0.993

Petersen estimates of the various strata or totals calculated from pooled data represent 84% - 112% of the estimates calculated with data stratified (Table 8), excluding estimates for jack populations. This represents a "bias" of only 6% - 12%, less than the maximum precision attained with these estimates (minimum ratio of CI/Total of 13%). The same holds true for estimates of jack populations, though the maximum bias and minimum CI/Total ratio are higher: 31% and 82%, respectively. Stratification of the data in this project thus does not influence bias of the Petersen estimates sufficiently to be of concern, with respect to the precision obtained. Trends are indicated by the comparisons, nevertheless, which may be of interest for formulating hypotheses (see discussion).

AGE, LENGTH AND SEX COMPOSITION

Scale samples from 434 fish were examined for age determination from dead pitch samples collected in 1987 and 624 fish collected in 1988. Of these, ages were determined for 271 (62.4%) and 485 (77.7%) respectively (Table 9). Many scales were unreadable due to the high degree of resorption.

The sex ratios in the estimated escapement of 1987 were 23.5% males to 69.4% females for the upper river, and 65.9% males to 32.4% females in the lower river (jacks represented 7.0 and 1.7 % of the fish in the two areas respectively) (Table 5). In 1988, there were 35.3% males, 63.8% females, and 0.8% jacks in the estimated upper river escapement and 52.2% males, 47.0% females, and 0.7% jacks in the lower river escapement (Table 6). This represents 54% males and 42.7% females in the total escapement (calculated with area strata) of 1987 and 47% males and 52% females in that of 1988. Jacks represented 3.2 and 0.7% of the total escapement in 1987 and 1988 respectively.

Age and Length Composition

Ages of the Kitsumkalum River chinook salmon in 1987 and 1988 ranged from 3.2 to 7.2 (Tables 10 and 11). Females tended to be older than males, as in the previous study (Andrew and Webb, 1988), 81% and 89% females being 6 years of age or older in 1987 and 1988 respectively, compared to 74 and 73% of the males in these respective years. Bias in readability of scales of females (see below) may have exaggerated this difference in 1988. Fish were also slightly older and more diverse in age composition in 1988 than in 1987; 7-year-old fish were absent in 1987 samples but present in 1988. Of all fish aged in 1987 and 1988, 97.4% left freshwater in their second year of life (sub (2) age classes) (Tables 10 and 11). This was also observed in the earlier study reported by Andrew and Webb (1988).

Six-year-old fish dominated both male and female populations of both 1987 and 1988 (Table 12), representing the 1981 and 1982 brood-years respectively.

Mean postorbital-hypural lengths of spawning fish of both sexes (excluding jacks) in 1987 and 1988 ranged from 878 to 955 mm (Tables 10 and 11). Mean lengths of age classes in separate sexes varied from 480 to 1,030 mm. Both males and females of the 5.1 age class in 1987 appeared exceptionally large, as did the 5.1 and 6.1 fish of 1988, but these were few in number. By river area, the largest mean-sized fish taken in the 1988 live-tagging effort were

Table 8. Comparison of Petersen estimates of chinook salmon escapement totals calculated with stratified or pooled data, 1987 and 1988.

Year	Strata	Petersen Estimate		Bias Pooled/Strat (%)	Precision CI / Total (%)	
		Stratified	Pooled		Stratified	Pooled
1987						
	Upper river	6,850	5,891	86	34	27
	Lower river	17,658	17,716	100	23	21
	Males	13,254	11,110	84	29	23
	Females	10,473	10,185	97	25	23
	Jacks	781	1,026	131	91	109
	Total (all pooled or all stratified)	24,508	23,422	96	19	16
	Total (sex only pooled)	24,508	23,606	96	19	17
	Total (area only pooled)	24,508	22,321	91	19	16
1988						
	Upper river	6,782	6,949	102	25	25
	Lower river	15,973	17,411	109	16	16
	Males	10,743	10,849	101	21	20
	Females	11,844	12,688	107	18	17
	Jacks	168	231	138	82	108
	Total (all pooled or all stratified)	22,755	25,523	112	14	13
	Total (sex only pooled)	22,755	24,361	107	14	13
	Total (area only pooled)	23,768	23,768	100	13	13

Table 9. Mean length and scale condition of Kitsumkalum River chinook salmon, 1987 and 1988.

Year	Sex	Scale condition	Number	Postorbital-hypural length (mm)			
				Mean	Standard deviation	95% C L	
						Lower	Upper
1987	Males	Readable	89	879	44	792	966
		Unreadable	59	912	84	742	1,082
	Females	Readable	182	955	43	871	1,039
		Unreadable	104	892	47	798	986
1988	Males	Readable	145	910	611	-288	2,108
		Unreadable	49	883	115	650	1,116
	Females	Readable	340	878	143	598	1,158
		Unreadable	90	882	45	792	972

Table 10. Age composition of Kitsumkalum River chinook salmon, 1987. (includes dead recovery only).

Sex	Age	Number of age determinations	% of total	Postorbital-hypural length (mm)			
				Mean	Standard deviation	95% C L	
						Lower	Upper
Males	4.2	6	7	547	45	500	594
	5.1	1	1	960	0	960	960
	5.2	16	18	778	62	738	818
	6.2	66	74	933	38	924	942
	Total	89	100	878	30	873	886
Females	5.1	8	4	883	49	839	927
	5.2	28	15	814	44	797	831
	6.1	1	1	890	0	890	890
	6.2	145	80	987	42	980	994
	Total	182	100	955	34	950	960
Jacks	3.1	1	25	460	0	460	460
	3.2	2	50	320	28	68	572
	4.2	1	25	490	0	490	490
	Total	4	100	398	14	375	420

Table 11. Age composition of Kitsumkalum River chinook salmon, 1988 (includes dead recovery only; no scale samples were taken during live tagging).

Sex	Age	Number of age determinations	% of total	Postorbital-hypural length (mm)			
				Mean	Standard deviation	95 % C L	
						Lower	Upper
Males	3.1	1	1	480	0	480	480
	4.1	2	1	685	21	496	874
	4.2	14	10	588	53	557	619
	5.1	2	1	920	71	282	1,558
	5.2	20	14	922	57	895	949
	6.1	1	1	1,030	0	1,030	1,030
	6.2	99	68	962	65	949	975
	7.2	6	4	883	34	847	919
	Total	145	100	910	45	902	917
Females	4.1	1	0	810	0	810	810
	5.1	5	1	866	44	811	921
	5.2	31	9	791	26	781	801
	6.1	1	0	950	0	950	950
	6.2	298	88	887	39	883	891
	7.2	4	1	923	35	844	1,002
	Total	340	100	878	34	874	882
Jacks	3.2	4	50	338	21	305	371
	4.2	3	50	497	35	410	584
	Total	7	100	418	20	393	442

Table 12. Petersen estimates of chinook salmon escapement allocated by age composition, 1987 and 1988. (Data from Tables 10 and 11, Petersen estimates are from data stratified by area. Male numbers do not include jacks).

Year	Age	Males		Females		Total	
		Number	Percent	Number	Percent	Number	Percent
1987	4.2	893	6.74	461	4.4	1354	5.71
	5.1	148	1.12	1,611	15.38	1759	7.41
	5.2	2,383	17.98	58	0.55	2441	10.29
	6.2	9,829	74.16	8,344	79.67	18173	76.59
Total		13,254	100	10,473	100	23727	100
1983	3.1	74	0.69	0	0	74	0.33
	4.1	148	1.38	34	0.29	183	0.81
	4.2	1,038	9.66	0	0	1038	4.59
	5.1	148	1.38	174	1.47	322	1.43
	5.2	1,481	13.79	1,080	9.12	2562	11.34
	6.1	74	0.69	34	0.29	108	0.48
	6.2	7,335	68.28	10,381	87.65	17717	78.44
	7.2	445	4.14	140	1.18	585	2.59
Total		10,743	100	11,844	100	22587	100

females found in the lower river (Table 13).

Biases in Age-Length Composition

Student's t-tests showed that there were was a significant difference between the mean length of females with readable and unreadable scales in 1987 (Table 9) ($t = 11.24$, 1270 df, $P < 0.05$; females with readable scales were larger), but not of males of 1987 nor of either sex in 1988.

CODED WIRE TAG RECOVERY

Recoveries

Coded wire tagged juvenile chinook released into the Kitsumkalum River from the 1981 and 1984 brood years were recovered in the tagging and dead recovery programs of 1987, and from the 1981, 1983, and 1984 brood years in 1988.

The numbers of fish examined for missing adipose fins during tagging and recovery efforts in 1987 and the numbers of adipose fin clips encountered in the different sex and area strata are summarized in Table 14. Only 21 adipose clipped fish were observed. The majority (19) of these marked fish were found in the upper river during both live tagging and dead recovery efforts. No adipose clips were found during dead recovery in the lower river. Mark rates were highest in the upper river (1.09% and 1.93% during live tagging and dead recovery, respectively) and lowest in the lower river (0.26% and 0% during live tagging and dead recovery, respectively) (Table 14). There was no significant difference between observed and expected adipose clip returns assuming no difference between mark rates of live tagging and dead recovery samples in the upper river in 1987 ($X^2 = 1.6$, df = 1, $P < 0.05$) nor in 1988 ($X^2 = 0.34$, df =1, $P < 0.05$), but a difference was detected in the lower river in 1988 ($X^2 = 5.06$, df = 1, $P < 0.05$). Lower river returns were insufficient to perform this test in 1987 in this area. Andrew and Webb (1988) indicate that this is a test of the effect of decomposing adipose clips on recovery results, but washing out of carcasses from the upper (where adipose clip returns are most abundant) to the lower river could also have the same effect. In both years, adipose clip returns are proportionately greater in the lower river during dead recovery than during live tagging.

The results of coded wire tag returns are summarized in four tables for each year which contain the following items:

1) the raw data and mark (adipose clip) rates for the calculations (Tables 14 and 15);

2) the total escapement of adipose clips estimated using samples from two sources: live tagging and dead recovery (Tables 16 and 17);

3) the weighted average of the total estimated adipose clips from the two methods of estimation (Table 18);

4) the weighted average of the total number of adipose clips partitioned between tag codes, and the hatchery contribution to the escapement by each tag code (Tables 19 and 20);

Table 13. Postorbital-hypural length composition of Kitsumkalum River chinook salmon at live-tagging , 1988 (No scale samples taken for ageing)

Sex	Location	Number of length determinations	Postorbital-hypural length (mm)			
			Mean	Standard deviation	95% C L	
					Lower	Upper
Males	Lower river	26	864	145	805	923
	Upper river	179	873	120	855	891
	Total	205	872	123	855	889
Females	Lower river	21	920	43	900	940
	Upper river	142	874	56	865	883
	Total	163	880	56	871	889
Jacks	Lower river	0	0	0	0	0
	Upper river	2	450	28	198	702
	Total	2	450	28	198	702

Table 14. Sample sizes and adipose clip rates for live tagging and dead recovery samples from chinook salmon in the Kitsumkalum River, 1987.

Sex	Sample size[a]				Number adipose clips observed											
	Tagging		Dead recovery		Upper river tagging[b]			Lower river tagging[b]			Dead recovery[c]		Mark rate (%)			
													Tagging		Dead recovery	
	Upper river	Lower river	Upper river	Lower river	Head kept	Tagged and released	Total	Head kept	Tagged and released	Total	Upper river	Lower river	Upper river	Lower river	Upper river	Lower river
	A	B	C	D	E	F	G	H	I	J	K	L	M=G/A x 100	N=J/B x 100	O=K/C x 100	P=L/D x 100
Male	523	442	213	539	6	1	7	1	0	1	4	0	1.34	0.23	1.88	0
Female	305	325	306	760	0	2	2	1	0	1	6	0	0.66	0.31	1.96	0
Jack	36	39	12	14	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0
Total excluding jacks	828	767	519	1299	6	3	9	2	0	2	10	0	1.09	0.26	1.93	0

[a] From table 5; sample size for tagging includes heads that were kept: e.g. upper river males (517 fish from Table 5) plus 6 from column E = 523

[b] From Appendix 1

[c] From Appendix 3

Table 15. Sample sizes and adipose clip rates for live tagging and dead recovery samples from chinook salmon in the Kitsumkalum River, 1988.

Sex	Sample size[a]				Number of adipose clips observed											
	Tagging		Dead recovery		Upper river tagging[b]			Lower river tagging[b]			Dead recovery[c]		Mark rate (%)			
													Tagging		Dead recovery	
	Upper river	Lower river	Upper river	Lower river	Kept head	Tagged and released	Total	Kept head	Tagged and released	Total	Upper river	Lower river	Upper river	Lower river	Upper river	Lower river
	A	B	C	D	E	F	G	H	I	J	K	L	M=G/A x 100	N=J/B x 100	O=K/C x 100	P=L/D x 100
Male	449	487	214	747	1	0	1	0	0	0	2	8	0.22	0.00	0.93	1.07
Female	332	392	378	1724	1	0	1	0	1	1	0	6	0.30	0.26	0.00	0.35
Jack	6	15	7	13	0	0	0	0	0	0	1	0	0.00	0.00	14.29	0.00
Total excluding jacks	**781**	**879**	**592**	**2471**	**2**	**0**	**2**	**0**	**1**	**1**	**3**	**14**	**0.26**	**0.11**	**0.51**	**0.57**

[a] From Table 6; sample size for tagging includes heads that were kept, e.g. upper river males (448 from Table 6) plus 1 (from column E) = 449.

[b] From Appendix 2

[c] From Appendix 4

Table 16. Estimates of the total escapement of adipose clippped chinook salmon to the Kitsumkalum River at live tagging and at dead recovery, 1987. (Data stratified by sex and area)

Location	Activity	Sex	Sample size	Adipose clips observed[b]			Petersen estimate of population size[a]	Percentage population sampled	Total estimated adipose clips		
				Obs.	95 % CL				Total	95 % CL	
					Lower	Upper				Lower	Upper
			A	B	B1	B2	C	D = A/C x 100	E = (B/A) x C	E = (B1/A) x C	E = (B2/A) x C
Upper river	Live tagging	Male	523	7	2.8	14.4	6,143	8.51	82	33	169
		Female	305	2	0.2	7.2	5,587	5.46	37	4	132
		Total	828				11,730	7.06	119		
Lower river	Live tagging	Male	442	1	0.1	5.6	7,111	6.22	16	2	90
		Female	325	1	0.1	5.6	4,886	6.65	15	2	84
		Total	767	2			11,997	6.39	31		
Whole river	Live tagging	Male	965	8			13,254	7.28	98		
		Female	630	3			10,473	6.02	52		
		Total	1,595	2			23,727	6.72	150		
Upper river	Dead recovery	Male	213	4	1	10.2	1,612	13.21	30	8	77
		Female	306	6	2.2	13.1	4,757	6.43	93	34	204
		Total	519	10			6,369	8.15	123		
Lower river	Dead recovery	Male	539	0	0	3.7	11,642	4.63	0	0	80
		Female	760	0	0	3.7	5,716	13.30	0	0	28
		Total	1,299	0			17,358	7.48	0		
Whole river	Dead recovery	Male	752	4			13,254	5.67	30		
		Female	1,066	6			10,473	10.18	93		
		Total	1,818	10			23,727	7.66	123		

[a] Dead recovery population sizes from Table 5; methods for calculating tagging population sizes are described in the text.

[b] 95% CL from tabulated Poisson distribution with B as the random value (see Ricker, 1975, p. 343)

Table 17. Estimates of the total escapement of adipose clipped chinook salmon to the Kitsumkalum River at live tagging and dead recovery, 1988 (Data stratified by sex and area)

Location	Activity	Sex	Sample size	Adipose clips observed [b]			Petersen estimate [a] of population size	Percentage population sampled	Total estimated adipose clips		
				Obs.	95 % CL				Total	95 % CL	
					Lower	Upper				Lower	Upper
			A	B	B1	B2	C	D = A/C x 100	E = (B/A) x C	E = (B1/A) x C	E = (B2/A) x C
Upper river	Live tagging	Male	449	1	0.1	5.6	4,388	10.23	9	1	55
		Female	332	1	0.1	5.6	4,582	7.25	14	1	77
		Total	781				8,970	8.71	23		
Lower river	Live tagging	Male	487	0	0	3.7	6,355	7.66	0	0	48
		Female	392	1	0.1	5.6	7,262	5.40	19	2	104
		Total	879				13,617	6.46	19		
Whole river	Live tagging	Male	936	1			10,743	8.71	9		
		Female	724	2			11,844	6.11	33		
		Total	1,660				22,587	7.35	42		
Upper river	Dead recovery	Male	214	2	0.2	7.2	2,397	8.93	22	2	81
		Female	378	0	0	3.7	4,329	8.73	0	0	42
		Total	592				6,726	8.80	22		
Lower river	Dead recovery	Male	747	8	3.4	15.8	8,346	8.95	89	38	177
		Female	1,724	6	2.2	13.1	7,515	22.94	26	10	57
		Total	2,471				15,861	15.58	115		
Whole river	Dead recovery	Male	961	10			10,743	8.95	111		
		Female	2,102	6			11,844	17.75	26		
		Total	3,063				22,587	13.56	137		

[a] Dead recovery population sizes from Table 6; methods for calculating tagging population sizes are described in the text.

[b] 95% CL from tabulated Poisson distribution with B as the random value (see Ricker, 1975, p.343)

Table 18. Weighted average estimates of total escapement of adipose clipped chinook salmon in Kitsumkalum River, 1987 and 1988.

Year	Sex	Total estimated adipose clips			
		Using tagging [a] sample	Using dead recovery [a] sample	Weighted [b] average	% of total
		A	B	C	
1987	Male	98	30	62	46
	Female	52	93	74	54
	Total	150	123	136	100
	Total sample	1595	1818		
1988	Male	9	111	75	72
	Female	33	26	28	28
	Total	42	137	104	100
	Total sample	1660	3063		

[a] Estimates taken from Tables 16 and 17, includes upper and lower river fish except jacks.

[b] $C = \frac{(\text{Total sample size, tagging, } x \quad A) \quad + \quad (\text{Total sample size, dead recovery, } x \quad B)}{\text{Total sample size tagging + Total sample size recovery}}$

Table 19. Estimates of total escapement of chinook salmon to the Kitsumkalum River of each CWT group, 1987

Brood year	Tag code	Observed CWT distribution[a]		Estimated CWT escapement[b]			Released		Total hatchery contribution
		Male A	Female B	Male C	Female D	Total E	Total F	Proportion marked G	E / G
1981	O22312	5	3	28.08	36.92	65.00	30,250	0.77	84.42
1981	O22313	5	3	28.08	36.92	65.00	70,400	0.42	154.76
1982	-								
1983	O22758			0.00	0.00		30,716	1.00	-
1984	O23347	1	0	5.62	0.00	5.62	26,409	0.99	5.68
Total[c]		11	6	61.77	73.84	135.61			244.86
No CWT /lost CWT			1						

[a] CWT's from fish of upper and lowr river live tagging and dead pitch that were sucessfully analysed (3 further adipose clipped fish were tagged and released)

[b] C = Total estimated male adipose clips (Table 18) x $\frac{A}{\text{Total decoded male tags}}$

[c] Totals for estimated adipose clipped/CWT escapement from Table 18

Table 20. Estimates of total escapement of chinook salmon to the Kitsumkalum River of each CWT group, 1988

Brood year	Tag code	Observed CWT distribution[a]		Estimated CWT escapement[b]			Released		Total hatchery contribution
		Male A	Female B	Male C	Female D	Total E	Total F	Proportion marked G	E / G
1981	O22312								
1981	O22313	1	1	7.52	5.69	13.21	70,400	0.42	31.45
1982	-								
1983	O22758	5	4	37.59	22.77	60.35	30,716	1.00	60.35
1984	O23347	1		7.52	0.00	7.52	26,409	0.99	7.60
1984	O23350	2		15.03	0.00	15.03	26,071	1.00	15.03
1985	O23705	1		7.52	0.00	7.52	42,499	0.99	7.60
Total[c]		10	5	75.17	28.46	103.63			122.03
No CWT/ lost CWT		1	1						

[a] CWT's from fish of upper and lower river live tagging and dead pitch that were successfully analysed (1 additional adipose clipped jack had no data collected and 1 further female was released)

[b] $C = \text{Total estimated male adipose clips (Table 18)} \times \frac{A}{\text{Total decoded male tags}}$

[c] Totals for estimated adipose clipped /CWT escapement are from Table 18.

5) the estimated hatchery contribution to the escapement by age class (Table 21).

Similar absolute numbers of adipose clips (20 fish) were recovered in 1988 as in 1987, but in 1988 their distribution in the river areas was more uniform (Table 15).

Estimated escapement for the two sampling schemes was similar in 1987 (150 and 123, respectively) but highest for dead recovery in 1988 (Tables 16 and 17). Weighted mean estimates from the two types of sampling (Table 18) indicate that escapement of adipose clips to the Kitsumkalum River was close to 100 in both years (136 in 1987 and 104 in 1988), but with females predominating in 1987 (54.4%) and males in 1988 (72.5%).

The estimates of adipose clipped fin escapement, particularly those based on live tagging, are not very accurate due to a number of factors:

1) The calculated confidence limits are up to 400 % of the escapement estimates. This is primarily influenced by the small number of adipose clipped fish that were recovered.

2) It is not clear which punch rates (i.e. sexes pooled, areas pooled, or individual) are the most appropriate for estimating the population size sampled during live tagging, as discussed earlier. The estimate of the distribution of escapement of adipose fin clipped fish from live tagging data between the river areas is thus also considerably influenced, which is of importance if stratified data is used for estimating total escapement.

The use of weighted means may reduce the effects of these factors, but the estimates of adipose clipped fish escapement should probably only be considered as an indication of trends.

Hatchery Contribution:

The estimated total escapements of each CWT group of fish recovered in the 1987 and 1988 escapements are presented in Tables 19 and 20, respectively. These are expanded (by mark rate at release, see Table 3) to include untagged hatchery fish associated with the same CWT code and to derive the total hatchery contributions to respective escapements in 1987 and 1988. In 1987 (Table 19), total hatchery contribution to escapement was estimated as 245 fish, with the majority originating from the heated pool-raised 1981 brood (155 fish), 84 from the normal 1981 brood, and 6 from 1984 spawning. In 1988 (Table 20), 122 hatchery fish were estimated to have returned. The origin of returning fish was considerably more diverse than in 1987, representing 1981 (heated pool), 1983, 1984, and 1985 spawnings. The principal source was the 1983 brood (60 fish returning). Males dominated returning fish in 1988 (Table 20), while females were more represented in 1987 (Table 19).

Hatchery fish represented 1.03% of the total estimated adult escapement of the Kitsumkalum chinook in 1987 (Table 21), and were almost entirely 6-year old fish. As detected by the sampling scheme used, all 3-year-old fish escaping to the Kitsumkalum in 1987 were of hatchery origin (this may be an overestimate due to the small representation by these fish in the escapement). In 1988, the hatchery contribution to escapement was 0.54% of the total (Table 21). The greatest relative contribution was by 3-year-old and 7-year-old fish.

Table 21. Estimated total contribution of chinook salmon of hatchery origin to age classes represented in the 1987 and 1988 escapements in Kitsumkalum River

Year	Age	Estimated[a] escapement	Hatchery[b] contribution	% Hatchery contribution
1987	3	0	6	100
	4	1,354		0
	5	4,200		
	6	18,173	239	1.32
	7	0		
	Total	23,727	245	1.03
1988	3	74	8	11
	4	1,220	23	2
	5	2,883	60	2
	6	17,824	0	0
	7	585	31	5
	Total	22,587	122	0.54

[a] Compiled from Table 12; differences in totals from those in Table 12 are due to rounding errors.

[b] From Tables 19 and 20.

WATER LEVEL

Figure 2 presents the water level measurements taken during the tagging programs in 1987 and 1988. Of particular interest is the high water in mid-September of 1988, which may have influenced the results of that year. Substantial high-water was observed in mid-September of 1987 as well, but full records of the water levels during both programs were not available.

DISCUSSION

POPULATION ESTIMATION

Escapement:

Petersen escapement estimates of chinook salmon to the Kitsumkalum River in 1987 and 1988 were 24,508 ± 4716 and 22755 ± 3083 respectively with data stratified for sex and area. This represents almost a two-fold greater return than observed in earlier years of the key stream program on the Kitsumkalum (11,825 in 1984, 8,308 in 1985, and 10,151 in 1986 (Andrew and Webb, 1988)) and is greater than the maximum total estimated chinook escapement for the Lower Skeena River statistical area prior to 1981 (Hancock et al., 1983). Even though the figures quoted by Hancock et al. are based on visual estimation procedures and no doubt are considerable underestimates (Cousens et al., 1982), this data indicates that the chinook run being studied improved considerably in 1987 and 1988. Many of the returns are from the 1982 year-class, when the hatcheries on the river were not yet in full production, so most of this improvement is due to better escapement of the natural stocks.

Estimation:

Escapement estimates by sex, area, and year were all affected differentially by such factors as tagging rate, tag recovery rate, and primary tag loss, as discussed by Andrew and Webb (1988) for the earlier studies:

1) More males than females were tagged in both years, but more females than males were recovered in both years;

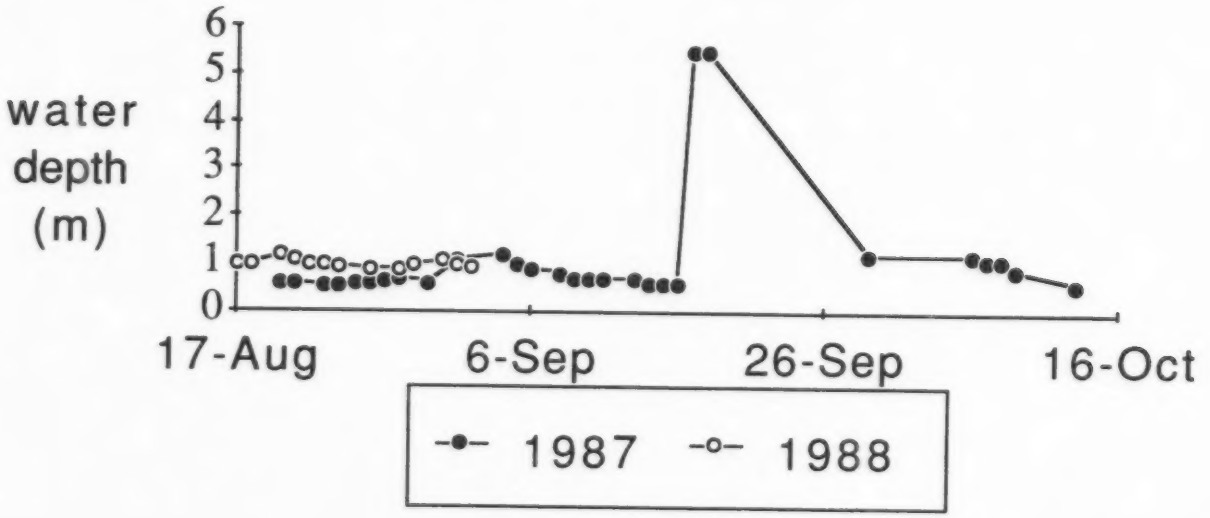
2) There was a tendency to tag larger males than were recovered, at least in 1988.

3) Tag recovery in the lower river area was always better than in the upper, to a large extent probably due to fish straying from the upper area (corrected for in the data stratified by yarea); and

4) Primary tag loss was apparently affected differentially by year and area.

As discussed by Andrew and Webb (1988), the literature also mentions differential effects of sex in salmon tagging programs: Wilson and Andrew (1987), Petersen (1954), Ward (1959),

Fig. 2 Water levels in the Kitsumkalum River during tagging studies, 1987 and 1988.



Eames and Hino (1981), Eames et al. (1981), and Shardlow et al. (1986) all indicate that males and females are sampled differentially in activities of a tagging program such as the present one.

Straying between the river areas, while reported as minimal in 1985 and 1986 (Andrew and Webb, 1988), was substantial in the two years covered by the present study, especially in 1987 (possibly due to higher water levels: 5.5 m peak reported in 1987-88 and 0.95m peak in 1985-86). The majority of strays were males originating from the upper river. Andrew and Webb (1988) suggest that males are more likely to return to the main river channel after spawning than females and are thus more prone to wash down out of the upper river after dying or in a weakened state. With higher water levels more male strays could be expected in the lower river, as observed in this study.

Tag loss of the Ketchum Kurl-lock ear tags was not a factor in population estimates in this study, as only secondary tag counts (opercular punches) were considered, but is of interest for future reference. Loss of the Ketchum Kurl-lock tags was highest in 1987 but was not influenced differentially by sex nor river area. Either tag application techniques or greater turbulence due to higher water levels could explain the greater tag losses in this year. However, differences in tag application techniques could be expected to result in a difference in tag losses in the two river areas as well (if distinct crews are used in the two areas) and the effect of turbulence could be expected to result in a gr. er apparent tag loss in the lower river (due to tag loss in fish washed through the canyon). Only the second of these trends was noted, though differences were not significant. Differences in behaviour of males and females may have been responsible for differential loss of tags used in the past (Andrew and Webb, 1988), but does not seem to influence retention of the Kurl-lock ear tags. Tag loss rates were quite low in both 1987 and 1988 compared to losses in earlier years, so the Kurl-lock ear tags seem considerably more reliable than both the Petersen discs and spaghetti tags used as primary tags in the earlier years.

Recognition rates of the opercular punches (analogous to tag loss rates) were not tested in this study. Re-pitching of some carcasses (Cousens et al., 1982) is recommended in future years to evaluate this factor.

Potential sources of bias and loss in accuracy are clearly present in the enumeration program. Ricker (1975) suggests that stratified sampling can counteract some biases resulting from non-random sampling and unequal sampling effort. Differential tagging and recovery rates by sex in the Kitsumkalum River chinook indicate that non-random sampling is occuring, and the methodology of the program suggests that sampling effort would be different in the two areas of the river. Andrew and Webb (1988) partitioned the data by sex (an approximation to stratification) and stratified sampling by area to circumvent bias in the estimates of escapement. Stratification of data in a more general sense can also increase the precision (i.e. reduce confidence intervals) of population estimates (Schaeffer et al., 1979) and provides additional information about the estimates (Ricker, 1975).

In the present study, Petersen estimates of escapement were made with data fully partitioned ("stratified"), "stratified" on single strata, and pooled over single or both strata (Table 8). Bias detected in this fashion for all estimates is less than the precision of the estimates, and, in most cases, less than 10%. Ricker (1975) indicates that differences between estimates of pooled and stratified data are generally greater than 10% if bias is present. It can probably be concluded that despite the identified potential sources of bias in the present project, actual bias eliminated by stratifying the data is minor relative to the precision obtained. Junge (1963) also indicates that bias can be minimal (< 10%) even with correlated non-random tagging and recovery. Stratification

(or "partitioning") of data, particularly by sex, may still be useful for providing additional information. Principal trends of interest identified by the analysis of biases in this fashion are:

1) bias from differences in area are greatest for jacks, which also provided the Petersen estimate of least precision, a signal that these estimates are not reliable;

2) the estimate for populations of males in 1987 are most affected by stratification by area while the estimate of numbers of fish in the upper river in 1987 is most affected by stratification by sex. This distinction is absent in 1988, and all biases (though minor) are in the opposite direction in 1988. All these factors may reflect the effects of greater and less well documented straying in 1987. Males are most affected by straying, and the smaller upper river escapement is influenced more (relatively) by the straying of a given absolute number of fish than is that of the lower river.

Confidence intervals for all Petersen estimates other than those for jacks (both years) and males in 1987 were less than 25% of the estimate, so sampling effort was adequate for all strata other than for jacks and males in the one year.

Mortality of females due to tagging in the present study, as in that by Andrew and Webb (1988), was apparently not significant. Most tagged recoveries were fully spent, and the proportion relative to the numbers recovered in either year were not significantly different from that of fully spent untagged female fish. Nevertheless, as in previous years, this could not be definitively demonstrated in the present study. The loss of carcasses and/or live fish to the Skeena River could also not be tested in the present study. Both factors would lead to an underestimation of true escapement.

Andrew and Webb (1988) indicate that 1985 and 1986 were exceptionally dry years in the study area, which may have resulted in some differences compared with the tagging program in 1987 and 1988. Recovery rates of opercular punches were higher in the earlier two years (17.4% and 16.6% in 1985 and 1986 compared with 7.8% and 12.0% in 1987 and 1988 respectively (see Table 4)).

AGE, SEX AND LENGTH COMPOSITION

As in the earlier years of this study (Andrew and Webb, 1988), males dominated the chinook run in 1987 to a slight degree (56% of the escapement total less jacks), while in 1988 they did not (48% of the escapement total less jacks). These differences are not great, and, considering that the confidence intervals of Petersen estimates of male and female escapements in 1987 and 1988 overlap (Tables 5 and 6), males and females can be assumed to be equally represented in the escapement.

Six-year-old fish that spent at least one year in fresh water made up the primary contribution to the escapement in 1987 and 1988, as in 1984 and 1986 (Andrew and Webb, 1988). Five-year-old fish were a considerably weaker component in 1987-88 than in 1984-86 (12-18% compared to 28-70% in the earlier years). Age class diversity in 1988 was comparable to that of 1984 and 1986, while in 1987 it was more uniform, like that observed in 1985.

The mean size of fish in 1987 (930 mm) was considerably larger than in previous years and 1988, while the 1988 mean size (875 mm) was comparable to those of 1986 (876 mm), and slightly larger than 1985 (857 mm) and 1984 (822 mm).

CODED WIRE TAG RECOVERIES

The coded wire tag recoveries suggest that 1.03% of the returning chinooks in 1987 and 0.54% of those in 1988 were of hatchery origin (Table 21). In absolute numbers, these were principally returns of 1981 brood year (heated pool) fish in 1987 and a mixture of 1981 (heated pool), 1983, and 1984 brood year fish in 1988. This represents a reduction in hatchery contribution to the escapement relative to earlier years, when up to 2.4% (1986) of the total returning fish (sexes pooled) were estimated to be of hatchery stock (Andrew and Webb, 1988). The large escapement of 1982 brood year fish, when no marking took place, explains this low contribution, particularly for 1988. Relative hatchery contribution to escapement for some individual age classes, particularly 3-year-old fish, was greater in 1987 and 1988 than earlier years.

Absolute escapement numbers of hatchery-origin fish in 1987 and 1988 were similar to those of 1985 and 1986. Hatchery contribution to escapement can be expected to increase in future years, as both marked and unmarked fish return from greater hatchery efforts.

Although we have tried to address as many potential sources of bias as possible in the estimation of the escapement of CWTs, the following additional factors have not been explicitly included:

1) selective removal and killing of adipose clipped fish captured during the tagging program, which reduces the adipose clip rate in the dead recovery and may thus influence the estimate of adipose clipped fish escapement from dead recovery samples,

2) patchy distribution of adipose clipped fish;

3) the low number of recoveries of adipose clips and decoded CWTs may make the precision of the estimates so low as to be of relatively little use; and

4) the sample of heads obtained for the decoding of CWTs may not be a random sample from the tagged population and might contain a bias due to size selectivity or other factors.

The first three points can be addressed to some extent while the small sample size and lack of data make it very difficult to assess the importance of bias in the sampling of heads for CWT analysis.

The estimated maximum number of tags eliminated from the dead pitch returns of a stratum (males in the upper river in 1987) by removal during tagging is just over 9 (Table 22). This could have a significant impact on estimations, given the low number of returns observed, so removal of these fish during tagging is not recommended.

Table 22. Effect of removal of adipose clipped chinook salmon during live tagging on potential mark recovery in the dead pitch in the Kitsumkalum River, 1987 and 1988.

Year	Location	Sex	% Population sampled in live tagging[a] A	% Population sampled in dead pitch[b] B	Number of clipped fish removed in tagging C	Estimated number of clipped fish missing from the dead pitch C x B / A
1987	Upper river	Male	8.51	13.21	6	9.31
		Female	5.46	6.43	0	0.00
	Lower river	Male	6.22	4.63	1	0.74
		Female	6.65	13.3	1	2.00
1988	Upper river	Male	10.23	8.93	1	0.87
		Female	7.25	8.73	1	1.20
	Lower river	Male	7.66	8.95	0	0.00
		Female	5.40	22.94	0	0.00

[a] See Tables 16 and 17

[b] Number of adipose clipped fish removed during live tagging (see Tables 14 and 15)

It is not possible to directly assess the patchiness of the distribution of adipose clipped fish, but differences in the mark rate between the upper and lower river indicate that differences between these two areas do exist. Differences in the mark rate of live tagging and dead recovery samples in the lower river in 1988 suggests that this patchiness may change over time. Stratification of the data by area is thus probably wise for estimating numbers of adipose clipped fish, but, because of greater uncertainty in estimating populations during tagging, care should be taken in using stratified data from live tagging samples.

The estimates of adipose clip escapement are quite imprecise (Tables 16 and 17) due to the low number of mark recoveries (all upper confidence intervals are greater than 100% of the estimate). The actual precision is probably less, since further unaccounted error is introduced by the use of Petersen estimates of population size at tagging and dead recovery in the calculations. The most critical improvement needed to increase precision of the CWT-based estimations is a larger number of mark returns. This could be achieved by either more tagging or recovery effort. More tagging effort will be represented by post-1982 hatchery fish as they return. For more recovery effort, it would be advisable to concentrate on dead recoveries, since accuracy is most affected by the actual number of returns, not reflected in weighted averages, and precision may be compromised by the uncertain estimation of fish populations during live tagging.

The Kitsumkalum River chinook appear to be responding well to management efforts, with the results being well detected by the tagging program. As such, the programs in this stream should be continued.

SUMMARY

1. Total escapement estimates for chinook salmon to the Kitsumkalum River using live tagging and subsequent recovery of carcasses were 24,508 in 1987 and 22,755 in 1988. These estimates were calculated from data stratified by sex and area. This represents approximately a two-fold increase over the escapements reported by Andrew and Webb (1988) for 1984 - 1986.

2. Stratification of the data by either sex or river area changes bias in the estimates of escapement less than the precision of the estimates.

3. Sampling effort was adequate to provide escapement estimates with confidence intervals of less than 25% of the total for males (except in 1987 for the stratified estimate) and females in both river areas, but not for jacks.

4. The escapements of chinook of both sexes in 1987 and 1988 were dominated by 6-year-old fish that had spent one year in fresh water.

5. Males and females were equally represented in the runs of both years.

6. The mean size of fish in 1987 (930 mm) was larger than that of 1988 (875 mm) and of that reported by Andrew and Webb (1988) for previous years.

7. The total estimated return of adipose clipped chinook salmon to the Kitsumkalum River was 136 in 1987 and 104 in 1988.

8. The total estimated hatchery contribution to the adult chinook escapement of the Kitsumkalum River was 245 fish in 1987 and 122 fish in 1988. This represents 1.03% and 0.54% of the total escapement in 1987 and 1988, respectively.

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APPENDICES

Appendix 1. Summary of live chinook salmon tagging data for the upper and lower Kitsumkalum River, 1987.

Location	Date	Males	Females	Jacks	Total	Coded Wire Tags
Upper river	21-Aug	25	36	4	65	
	22-Aug	27	24	2	53	
	24-Aug	39	18	8	65	1 female released
	25-Aug	44	34	6	84	
	26-Aug	40	23	4	67	1 male killed
	27-Aug	26	14	6	46	
	28-Aug	53	21	0	74	
	29-Aug	48	12	1	61	1 male killed
	31-Aug	50	28	3	81	1 male killed
	1-Sep	19	8	0	27	
	2-Sep	23	6	0	29	
	3-Sep	25	0	0	25	
	4-Sep	21	23	1	45	1 male killed
	5-Sep	25	21	0	46	1 female released
	7-Sep	45	28	1	74	2 males killed
	8-Sep	7	9	0	16	1 male released
TOTAL		517	305	36	858	6 males (k), 1 (r); 2 females (r)
Lower river	20-Aug	20	22	6	48	1 male killed
	21-Aug	28	12	1	41	
	23-Aug	31	16	1	48	
	24-Aug	52	25	5	82	
	25-Aug	45	22	7	74	
	26-Aug	41	26	4	71	
	27-Aug	40	21	4	65	
	28-Aug	52	50	5	107	
	30-Aug	2	7	2	11	
	1-Sep	16	10	0	26	
	4-Sep	47	38	2	87	
	5-Sep	28	44	2	74	1 female killed
	6-Sep	39	31	0	70	
TOTAL		441	324	39	804	1 male (k), 1 female (k)

Appendix 2. Summary of live chinook salmon tagging data for the upper and lower Kitsumkalum River, 1988.

Location	Date	Males	Females	Jacks	Total	Coded wire tags
Upper river	18-Aug	7	13	0	20	
	19-Aug	11	4	0	15	
	20-Aug	0	1	0	1	
	22-Aug	19	12	0	31	
	23-Aug	11	6	1	18	
	24-Aug	11	4	0	15	
	25-Aug	22	7	1	30	
	26-Aug	27	6	1	34	
	27-Aug	19	13	0	32	
	29-Aug	14	4	0	18	
	30-Aug	19	19	1	39	
	2-Sep	22	13	0	35	
	3-Sep	21	11	0	32	
	5-Sep	51	25	0	76	
	6-Sep	50	39	2	91	
	7-Sep	56	60	0	116	
	8-Sep	63	66	0	129	1 male, 1 female
	9-Sep	25	28	0	53	(both killed)
TOTAL		448	331	6	785	1 male, 1 female
Lower river	17-Aug	14	10	0	24	
	18-Aug	9	11	0	20	
	20-Aug	16	15	2	33	
	21-Aug	26	27	1	54	
	22-Aug	39	37	2	78	
	23-Aug	50	39	3	92	
	24-Aug	38	36	3	77	
	26-Aug	79	61	1	141	
	28-Aug	31	37	1	69	
	29-Aug	64	50	1	115	
	31-Aug	53	24	0	77	
	1-Sep	54	30	1	85	1 female
	2-Sep	14	15	0	29	(released)
TOTAL		487	392	15	894	1 female

Appendix 3. Summary of dead pitch recovery data for chinook salmon in the upper and lower Kitsumkalum River, 1987.

Location	Date	Fish pitched				Punched recoveries														Scale samples	CWT	
						Tagged in upper river							Tagged in lower river									
		M	F	J	Total	Males		Females		Jacks		Total	Males		Females		Jacks		Total		M	F
						1	2	1	2	1	2		1	2	1	2	1	2				
Upper river	24-Aug	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	27-Aug	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	1-Sep	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	7-Sep	6	3	0	9	2	0	0	0	0	0	2	0	0	0	0	0	0	0	5	0	0
	9-Sep	2	4	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1
	11-Sep	8	19	0	27	3	1	3	1	0	0	8	0	0	0	0	0	0	0	17	0	0
	12-Sep	9	7	1	17	1	0	0	0	0	0	1	0	0	0	0	0	0	0	11	0	1
	14-Sep	21	22	0	43	4	0	2	0	0	0	6	0	0	0	0	0	0	0	18	0	1
	15-Sep	33	23	2	58	5	0	0	0	0	0	5	0	0	0	0	0	0	0	16	0	0
	16-Sep	20	21	4	45	3	1	1	0	0	0	5	0	0	0	0	0	0	0	15	0	2
	17-Sep	25	25	0	50	2	1	1	0	0	0	4	0	0	0	0	0	0	0	15	1	0
	19-Sep	32	35	4	71	4	2	1	0	0	0	7	0	0	0	0	0	0	0	11	2	0
	28-Sep	22	59	1	82	2	1	2	0	0	0	5	0	0	0	0	0	0	0	9	0	1
	29-Sep	13	37	0	50	0	0	4	0	0	0	4	0	0	1	0	0	0	1	10	0	0
	30-Sep	2	8	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
	7-Oct	6	12	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
	8-Oct	1	15	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15-Oct	11	15	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total 1[a]						26		13		0		39	0		1		0		1			
Total 2[b]							6		1		0	7		0		0		0				
TOTAL		213	306	12	531	32		14		0		46	0		1		0		1	141	4	6
Lower river																						
	8-Sep	7	19	0	26	0	0	0	0	0	0	0	0	0	4	1	0	0	5	27	0	0
	9-Sep	16	12	2	30	1	1	0	0	0	0	2	1	1	3	0	0	0	5	30	0	0
	10-Sep	17	18	0	35	1	0	0	0	0	0	1	1	0	2	0	0	0	3	35	0	0
	11-Sep	10	15	0	25	0	0	0	0	0	0	0	0	0	4	0	0	0	4	24	0	0
	13-Sep	15	28	0	43	0	0	0	0	0	0	0	1	0	1	1	0	0	3	43	0	0
	14-Sep	20	33	4	57	0	0	0	0	0	0	0	2	0	4	0	0	0	6	57	0	0
	15-Sep	34	57	2	93	1	1	0	0	0	0	2	2	0	2	4	0	1	9	21	0	0
	16-Sep	26	41	2	69	0	0	0	0	0	0	0	0	0	4	0	0	0	4	26	0	0
	17-Sep	18	40	1	59	2	1	0	0	0	0	3	1	0	2	0	0	0	3	29	0	0
	18-Sep	24	51	3	78	0	0	0	0	0	0	0	2	0	7	0	0	0	9	9	0	0
	29-Sep	50	62	0	112	2	0	1	0	0	0	3	0	0	0	0	0	0	0	3	0	0
	6-Oct	52	59	0	111	0	2	1	2	0	0	5	0	0	0	0	0	0	0	0	0	0
	7-Oct	50	67	0	117	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
	8-Oct	52	68	0	120	0	1	0	0	0	0	1	1	1	0	0	0	0	2	0	0	0
	9-Oct	37	42	0	79	1	0	0	1	0	0	2	0	1	0	1	0	0	2	0	0	0
	13-Oct[c]	63	94	0	157	2	0	1	0	0	0	3	0	0	2	1	0	0	3	0	0	0
	13-Oct[c]	30	28	0	58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14-Oct	18	26	0	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total 1[a]						10		4		0		14	11		35		0		46			
Total 2[b]							8		3		0	11		3		8		1	12			
TOTAL		539	760	14	1313	18		7		0		25	14		43		1		58	304	0	0

[a] Fish that have primary tags at the time of capture

[b] Fish that have lost their primary tags at the time of capture and have only opercular punches to identify them

[c] Represents information from a second crew working on Oct 13.

Appendix 4. Summary of dead pitch recovery data for chinook salmon in the upper and lower Kitsumkalum River, 1988.

Location	Date	Fish pitched					Punched recoveries											Scale samples	CW T		
							Tagged in lower river						Tagged in upper river								
		M	F	J	Other	Total	Males		Females		Jacks		Total	Males		Females		Jacks		Total				
							1	2	1	2	1	2		1	2	1	2	1	2			M	F	J
Upper river	20-Aug	1	0	0		1	0		0		0		0	0		0		0		0	1	0	0	0
	26-Aug	1	0	0		1	0		0		0		0	0		0		0		0	1	0	0	0
	27-Aug	1	0	0		1	0		0		0		0	0		0		0		0	1	0	0	0
	29-Aug	3	2	0		5	0		0		0		0	1		0		0		1	5	0	0	0
	30-Aug	1	0	0		1	0		0		0		0	1		0		0		1	1	0	0	0
	2-Sep	4	9	0		13	0		0		0		0	1		3		0		4	13	0	0	0
	3-Sep	6	7	1		14	0		0		0		0	3		3		0		6	14	0	0	0
	6-Sep	0	2	0		2	0		0		0		0	0		0		0		0	2	0	0	0
	7-Sep	2	0	0		2	0		0		0		0	0		0		0		0	2	2	0	0
	8-Sep	2	3	0		5	0		0		0		0	1		0		0		1	3	0	0	0
	9-Sep	3	1	1		5	0		0		0		0	1		0		0		1	5	0	0	0
	10-Sep	4	2	1		7	0		0		0		0	0		0		0		0	7	0	0	0
	12-Sep	12	5	0		17	1		0		0		1	1		0		0		1	15	0	0	0
	13-Sep	13	16	0		29	0		0		0		0	2		0		0		2	20	0	0	0
	15-Sep	19	19	0		38	0		0		0		0	2		1		0		4	21	0	0	0
	16-Sep	13	16	1		30	0		0		0		0	2		0		1		3	8	0	0	1
	17-Sep	17	24	0		41	0		0		0		0	2		0		5		7	13	0	0	0
	20-Sep	24	52	0		76	0		0		0		0	3		0		2		5	12	0	0	0
	22-Sep	31	70	0		101	0		1		0		1	2		0		7		10	4	0	0	0
	23-Sep	19	38	1		58	0		0		0		0	1		0		0		1	31	0	0	0
	24-Sep	12	28	2		42	1		0		0		1	1		0		1		2	24	0	0	0
	27-Sep	9	38	0		47	0		0		0		0	0		0		2		2	0	0	0	0
	28-Sep	9	12	0		21	0		0		0		0	0		0		0		0	0	0	0	0
	4-Oct	6	33	0		39	0		0		0		0	0		0		0		0	0	0	0	0
	6-Oct	2	1	0		3	0		0		0		0	0		0		0		0	0	0	0	0
Total 1[a]						599	2		1		0		3	24		25		0		49		2	0	1
Total 2[b]															1		1			2				
TOTAL		214	378	7	10[c]	609	2		1		0		3	25		26		0		51	203		3[d]	
Lower river																								
	12-Sep	33	57	4		94	3		4		0		7	0		0		0		0	73	1	3	0
	13-Sep	47	66	1		114	6	1	7	1	0		15	0		0		0		0	37	1	1[e]	0
	14-Sep	31	79	2		110	6		4		0		10	1		0		0		1	79	1	0	0
	15-Sep	20	46	1		67	2		6		0		8	1	1	0		0		2	48	0	0	0
	16-Sep	58	76	1		135	3	1	4		0		8	0	1	1		0		2	52	0	0	0
	19-Sep	40	84	1		125	2	1	5		0		8	1		0		0		1	41	0	0	0
	21-Sep	57	149	0		206	3		2		0		5	0		0		0		0	21	0	0	0
	22-Sep	118	182	2		302	1		8		0		9	2		1		0		3	40	0	0	0
	23-Sep	50	242	0		292	0		7	1	0		8	2		0		0		2	44	2	1	0
	26-Sep	110	285	0		395	5		14		0		19	2		0		0		2	4	1	1	0
	27-Sep	114	304	0		418	5		16		0		21	3		0		0		3	3	2	0	0
	28-Sep	43	101	0		144	4		3	2	0		9	0		0		0		0	0	0	0	0
	5-Oct	18	36	0		54	0		0		0		0	0		0		0		0	0	0	0	0
	7-Oct	10	17	1		28	0		1		1		2	0		1		0		1	0	0	0	0
Total 1[a]							38		85		1		124	12		3		0		15		8	6	0
Total 2[b]								3		4			7		2					2				
TOTAL		749	1724	13		2484	41		89		1		131	14		3		0		17	442		14[f]	

[a] Fish that have primary tags at the time of capture
[b] Fish that have lost their tags at the time of capture and have only opercular punches to identify them
[c] Fish were too decomposed to sex. The total number of fish in the sample was 609
[d] 3/3 heads taken for analysis.
[e] Female with head too decomposed to sample.
[f] 13/14 heads taken for analysis